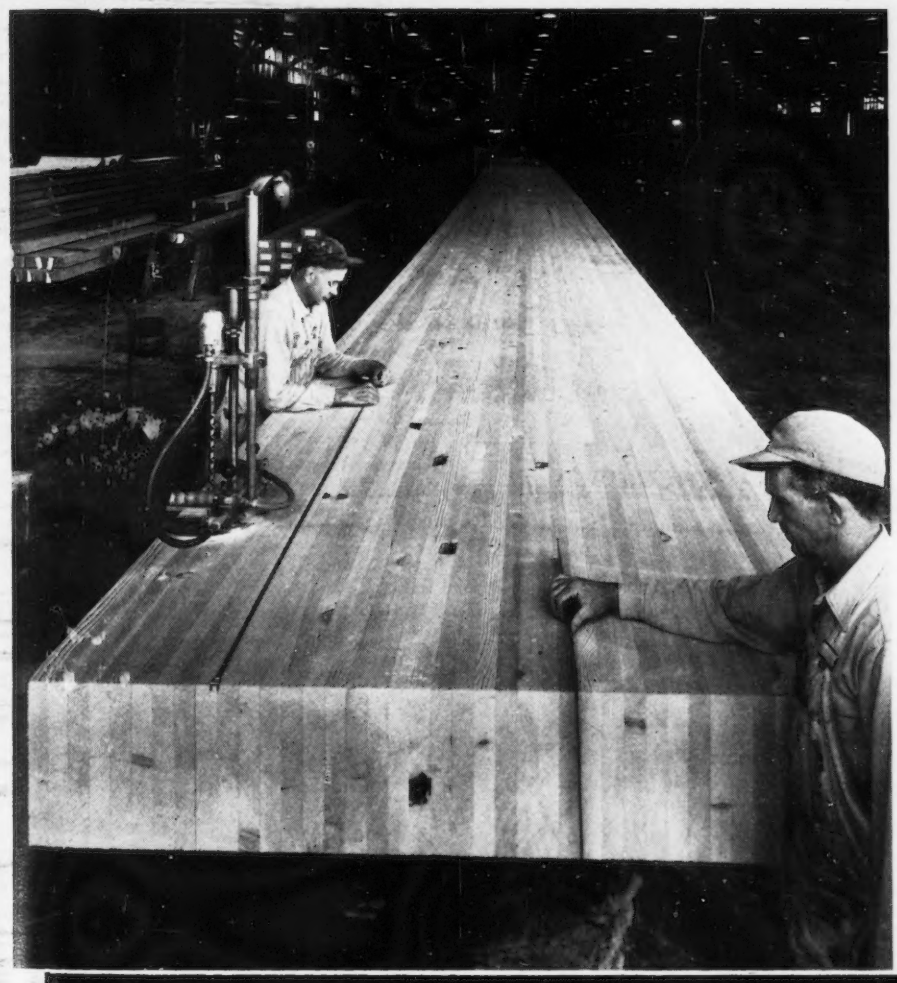
FOREST PRODUCTS JOURNAL

FOREST PRODUCTS RESEARCH SOCIETY



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1960/FEBRUARY

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Laminated girders for bridge in Manitoba. Designed to support 18-foot roadway, each contains 12, 800 FBM Douglas-Fir and 500 lbs. phenol-resorcinol.—*Timber Structures, Inc.*

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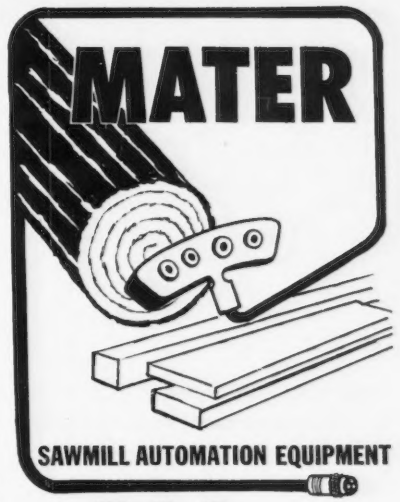

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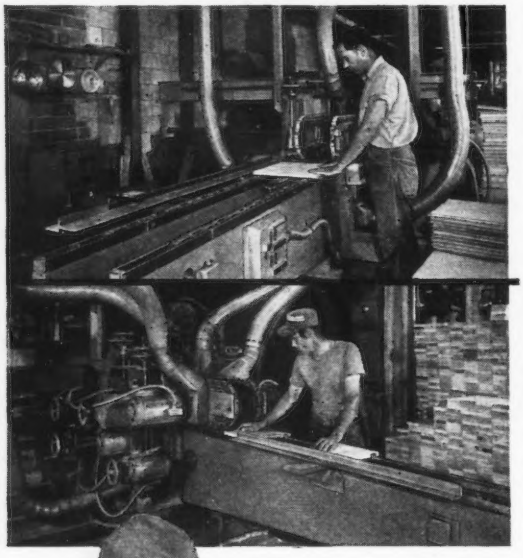

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Victor Knies, Prod. Mgr. at Jasper Corporation, shows typical cuts made on a Mereen-Johnson 441-A Gang Rip Saw.

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FPRS News-Digest

Important FPRS Dates

April 12–13, 1960: Joint meeting Inland Empire Section and Northwest Wood Products Clinic, Spokane, Wash.

April 28–29, 1960: Northern California Section Meeting, San Francisco, Calif.

April 28–29, 1960: Upper Mississippi Valley Section Meeting, Duluth, Minn.

June 5–9, 1960: Fourteenth National Meeting, Montreal, Canada.

"The General Public's Stake in Forest Products"

Scene of FPRS 14th National and first International meeting will be picturesque Montreal—"Paris of America."

18 Technical Sessions, 14 Division Workshops, Wide Range of Membership Business Featured at June 5–9 Montreal International Meet

The new Hilton Queen Elizabeth hotel in picturesque Montreal will be the site of FPRS 14th National, and its first International Meeting.

Registration Starts June 5

Registration facilities will be open from 1:00 to 8:00 p.m. on Sunday, and continue through the week. Fee of $12 for members and $14 for non-members will include admission to all sessions, and Division meetings; and copy of the Official Program including summaries of 60–70 papers to be presented.

Wide Range of Activities

In keeping with FPRS Annual Meetings, a variety of social activities, ladies program, luncheons, traditional "Paul Bunyan" hour, and gala FPRS Banquet are being scheduled. An important aspect of the meeting, plant tours to nearby laboratories and industry operations, is being organized.

A.I.W.E. to Meet Concurrently

Tuesday evening, June 7, is being kept relatively clear of FPRS activities in order to provide time for the Second Annual Meeting of the American Institute of Wood Engineering, combining a business meeting and technical program for representatives of the organization which now numbers close to 200.

The program, as reported to date, follows.

GENERAL

Monday, June 6, 8:45-12:30 p.m.

"FPRS Honorarium Lecture," Dr. A. J. Stamm, School of Forestry, North Carolina State College, Raleigh, N. C.; sponsored by the FPRS Midwest Section.

WOOD PRESERVATION

Monday, June 6, 2:00-4:30 p.m.

Program Chairman, R. H. Bescher, Assistant to Vice-President, Koppers Company, Inc., Pittsburgh 19, Pa.

PACKAGING

Monday, June 6, 2:00-4:30 p.m.

Program Chairman, Karl Bollerslev, Boise Cascade Corp., Box 290, Boise, Idaho.

"Problems Relative to Use of Container Board and Wood from Consumer Viewpoint," W. L. Newman, Mgr., Packagin Division, Services and Packaging Lab General Electric Co., Schnectady, N. Y and T. J. Luddy, NWBA, Washingtor D. C.

"Packaging Design — Using Wood an Wood Products," Albert Kner, Design En gineer, Container Corp. of America.

CHEMICAL UTILIZATION

Monday, June 6, 2:00-4:30 p.m.

Program Chairman, F. G. Perry, Jr., A. D Little Co., 30 Memorial Drive (Acor Park), Cambridge, Mass., and Mrs. Clair Canty, A. D. Little Co., 30 Memorial Driv (Acorn Park), Cambridge, Mass.

Wood Machining

Tuesday, June 7, 8:45-11:30 a.m.

Program Chairman, N. C. Franz, Univ. of Michigan, Ann Arbor. Presiding Chairman C. P. Berolzheimer, Calif. Cedar Products Co., Stockton, Calif.

"Machinery Research," William McKenzie, Univ. of Michigan, (on leave from FPL, Melbourne, Australia)

"Stress Analysis in Circular Headsaws," G. W. Andrews and J. S. Johnston, FPLC, Ottawa.

"Russian Motion Picture on Machining," Richard Perkins, N. Y. State College of Forestry, Syracuse, N. Y.

"Appraisal of Foreign Activities in Wood Machining," Les Reineke, USFPL, Madison, Wis.

WOOD FINISHING

Tuesday, June 7, 8:45-11:30 a.m.

Program Chairman, N. C. Hatcher, Jr., Drexel Furniture Co., Drexel, N. C.

"Research on Wood Finishes," H. N. Johnston, Battelle Memorial Institute, Columbus, Ohio.

"Wood Finishes—How Good Are They?" J. A. Hager, Grand Rapids Varnish Corp., Grand Rapids, Mich.

"Production Finishing Problems," G. M. Hill, Drexel Furniture Company, Drexel, N. C.

"The Importance of Wood Finishes," Leon Offman, Art Shop, Toronto, Canada.

CHEMICAL UTILIZATION

Tuesday, June 7, 8:45-11:30 a.m.

Program Chairman, F. G. Perry, Jr., A. D. Little Co., 30 Memorial Drive (Acorn Park), Cambridge, Mass., and Mrs. Claire Canty, A. D. Little Co., 30 Memorial Drive (Acorn Park), Cambridge, Mass.

GLUES & GLUING

Tuesday, June 7, 2:30-5:00 p.m.

Program Chairman, B. S. Bryant, Assoc. Prof., College of Forestry, Univ. of Washington, Seattle.

"Estimating Bond Quality in Plywood," Philip Northcott, FPLC, Vancouver.

"Contact Cements for Wood Gluing," H. F. Blomquist, USFPL, Madison, Wis.

"The Effect of the Wettability of Wood on Glue Line Behavior of Two Urea Resin Adhesives," H. G. Freeman and F. F. Ingaard, Yale Univ. School of Forestry, New Haven, Conn.

LUMBER MANUFACTURING

Tuesday, June 7, 2:30-5:00 p.m.

Program and Presiding Chairman, M. H. Mater, Mater Engineering, Corvallis, Ore. Recorder, Paul Heller, Mgr., Pacific Pine Lumber Co., New Westminster, B. C., Canada. Panel Moderator, Col. J. H. Jenkins, Director, FPL of Canada, Department of Northern Affairs and National Resources, Ottawa, Ontario, Canada.

"The Future of Hardwood Industry in Eastern Canada and Northeastern Canada," George French, Hay & Co., Ltd., Woodstock, Ontario, Canada.

"Economics of a Small Hardwood Sawmill," Don Cuppett, Forester, Union Carbide Chemicals Co., Charleston, W. Virginia.

"The Future of the Lumber Industry in Eastern Canada," Frank Rook, President, Pembroke Shook Mills, Pembroke, Ontario, Canada.

"Cost Reduction in Lumber Handling," J. R. Bemis, Ozan Lumber Co., Prescott, Ark.

MERCHANDISING

Tuesday, June 7, 2:30-5:00 p.m.

Program Chairman, Prof. William Lloyd, Dept. of Forestry, Michigan State Univ., East Lansing.

GLUES & GLUING

Wednesday, June 8, 8:30-11:30 a.m.

Program Chairman, Prof. B. S. Bryant, College of Forestry, Univ. of Washington, Seattle.

"Automating Glue Spreading and Lay-up," —Joint panel with Veneer and Plywood Division.

"Automating Possibilities," Henry Preusser, Technical Service Mgr., Adhesives, Resins, and Chemical Division, American Marietta Co., Seattle, Wash.

"Automating Possibilities with Dry Film Glue Line," R. K. Stensrud, Technical Div., Reichhold Chemicals, Inc., Seattle, Wash.

LOGGING

Wednesday, June 8, 8:30-11:30 a.m.

Program and Presiding Chairman, J. A. Doyle, FPL of Canada, Ottawa.

INDUSTRY-EDUCATION

Wednesday, June 8, 8:30-11:30 a.m.

Program Chairman, Dr. Everett Ellis, School of Natural Resources, Univ. of Michigan, Ann Arbor.

WOOD COMPOSITION BOARD

Thursday, June 9, 9:00-11:30 a.m.

Program Chairman, A. L. Mottet, Long–Bell Division, International Paper Co., Longview, Wash.

Presiding Chairman, J. R. Roberts, U. S. Gypsum Corporation, Palatine, Ill.

"Significance of Recent Developments in the Production and Use of Hardboard from the Mill Manager's Point of View," O. B. Eustis, Mgr., Hardboard Plant, Abitibi Corp., Alpena, Mich.

"Effect of Fiber Characteristics on Hardboard Properties," Dr. Dale Turner, Mgr. of Research, Masonite Corp., Laurel, Miss.

International Fibre Board Limited—Paper on insulating board.

"The Emerite Process of Hardwood and Semi-Hardboard Manufacture," R. C. Williams, President, Emerite Corp., Jackson, Miss.

QUALITY CONTROL

Thursday, June 9, 9:00-11:30 a.m.

Program and Presiding Chairman, Dr. J. R. Stillinger, Technical Director, Cascades Plywood Corp., Lebanon, Ore.

WOOD DRYING

Thursday, June 9, 9:00-11:30 a.m.

Program and Presiding Chairman, R. S. Millett, Seasoning Research Division, FPL of Canada, Ottawa.

Also: Informal discussion on research at FPLC, Ottawa, on kiln-drying of white pine as affected by chemical brown stain and moisture pockets.

WOOD COMPOSITION BOARD

Thursday, June 9, 2:00-4:30 p.m.

Program Chairman, A. L. Mottet, Long–Bell Division, International Paper Company, Longview, Wash.

Recorder, Dr. Dale Turner, Mgr. of Research, Masonite Corp., Laurel, Miss.

Presiding Chairman, Kjell Stordalen, Wynewood Products Corp., Jacksonville, Texas.

"Show-through of Particle Board Cores as Evaluated by a New Technique," Bruce Heebink, USFPL, Madison, Wis.

"Factors Affecting Show-through of Particle Boards," Dr. Max Yan, Director of Research, Abitibi Corp., Ontario, Canada.

"European Approach to and Experience With Particle Board Standards," Dr. Wilhelm Klauditz, Institute for Wood Research, Braunschwig, Germany.

VENEER & PLYWOOD

Thursday, June 9, 2:00-4:30 p.m.

Program Chairman, J. L. Lutz, USFPL, Madison, Wis.

"New Plywood Uses Developed by Structural Research," David Countryman, Chief of Applied Research, DFPA, Tacoma, Wash.

"Commercial Standards for Hardwood Plywood Products," William Groah, Lab. and Inspec. Mgr., Hardwood Plywood Institute, Arlington, Va.

"Linear Programming in the Plywood Industry," Ernest Koenigsberg, Mgr. of Mgmnt. Sciences, Division of Touche, Ross, Bailey & Smart, Certified Public Accountants.

WOOD COMPOSITION BOARD

Thursday, June 9, 2:00-4:30 p.m.

Recorder, R. W. Young, Long–Bell Div. International Paper Co., Longview, Wash.

"Advantages of the End-Use Approach to Particle Board Standards," James Hamilton, Mich. College of Mining & Technology, Houghton, Mich.; and Dr. George Marra, Washington State Institute of Technology, Pullman, Wash.

"Advantages of the Properties Classification Approach to Particle Board Standards," Wayne Lewis, USFPL, Madison, Wis.; and Sigurd Johnson, N. C. State College.

SECTIONS in the NEWS

Upper Mississippi Valley to Meet at Duluth, April 28–29

The spring meeting of the Upper Mississippi Valley Section will be held in the Duluth area, on Thursday and Friday, April 28 and 29. The theme will be "Reconstituted Wood Product Plant Operations." The meeting will feature conducted bus tours to unique hardboard, particle board, and allied manufacturing operations. Times are being arranged so that persons within a radius of 500 miles can fly to and from the meeting within the two-day span, conserving their work schedules. A social hour and dinner with an outstanding speaker are planned for Thursday evening. For details, write: Steve Wise, Wood Conversion Co., Cloquet, Minn.

Northern California Section Spring Meeting, April 28–29

"Aspects of Plywood Manufacture" will be the theme of the spring meeting of the Northern California Section of FPRS, according to David L. Brink, the Section's secretary–treasurer.

The tentative program will include sessions on manufacturing, finishing specifications and uses, and marketing aspects.

Headquarters for the two-day meeting will be the Sheraton–Palace Hotel, San Francisco, Calif. A banquet is planned at the Sheraton–Palace for the evening of April 28.

Mid-South Section to Sponsor Air Tour to Europe in April

Members of FPRS Mid-South Section, and others desiring to participate, are arranging to charter a special airplane to visit the Hannover Fair and wood research and industrial organizations in Germany and adjacent countries.

The group will leave New York City the evening of April 29 and arrive in Hannover the next morning. The flight will be via German Lufthansa Airlines Super-G Constellation, with a maximum of 82 persons. Round trip fare, which includes transportation only, will be approximately $250.00 a person. The party will return by way of Paris, May 14.

Note: Available space is going fast and may be sold out by the time this issue is in the mail. However, interested FPRS members may request additional information through the Executive Office.

National Executive Board Considers Long-Range Plans and Goals for the Society's Future

Executive Board in session, left to right: J. L. Love, W. J. Eason, W. R. Smith, F. J. Rovsek, T. S. Veazey, Jr., R. H. Berry, D. K. Saunders, F. E. Dickinson, J. J. Allegretti.

A. F. Muschler, H. O. Fleischer, S. B. Preston, D. K. Saunders, R. H Berry, and C. M. Kreider (not pictured) comprise newly appointe committee to study Division structure.

New policy-recommending committee formed to study goals . . . "Report of Progress" to be presented at National Meeting in Montreal.

Nine members of the FPRS National Executive Board met, January 19 and 20, in Chicago to discuss immediate and long-range activities of concern to the Society's almost 4,000 members. Unable to be present, were Col. John Jenkins, of Ottawa, because of a preceeding Canadian lumber industry meeting, and president Dr. E. S. "Scotty" Harrar, who is recuperating from a prolonged illness.

Raymond Berry, president-elect, was named acting president until Dr. Harrar can return to the "active" list, which is expected prior to the Montreal International Meeting.

Air-Tour to Europe

Among a number of actions, the Board approved the request of the Mid-South Section to sponsor an "FPRS Air-Tour to Europe" the last two weeks in April. Purpose will be to enable FPRS members to visit various industry and research organizations in Europe.

Financial Statement

It was noted that the national operations of the Society "broke even" during 1959, with income and expenditures of roughly $89,000. The official auditor's report will be published in an early issue of the *Journal*. The operating budget for 1960, reflecting a modest increase in expenditures for the *Journal*, is on an approximate $89,000 base. Dr. E. G. Locke, chairman of the Publications Committee, stressed the need for additional funds to be placed in the *Journal* budget in order to improve our publishing services to the membership. The Board, recognizing this need, is prepared to go to the membership for such added funds, and will report its program in March.

Plans for Future

Much of the meeting was devoted to an appraisal of FPRS progress to date, since its organization in 1947, and a projection of plans for the decade ahead. To present such a "Report of Progress" to the membership, a special policy-recommending committee of the Board has been appointed. It will make its report at the Montreal meeting. Members include, W. J. Eason, Don Saunders, Dr. Fred Dickinson, Walton Smith, and Raymond Berry.

Membership Drive

T. S. Veazey, Jr., national membership chairman, reported that the Society's membership had risen approximately 10 per cent in 1959. He proposed an enlarged and strengthened national committee consisting of six Regional membership chairmen, to be appointed, who in turn will work closely with the Section membership chairmen appointed by the Society's 14 Sections.

Honorarium

The Society accepted the Hitchcock Publishing Co. (publishers of Hitchcock's Woodworking) proposal to award an annual $500 grant, to be used by the Society as an honorarium to recognize outstanding research or career accomplishment at the professional and industrial level of the forest products industry. The details will be announced at the forthcoming international meeting.

Publication Schedule

John McDonald, editor of the *FP Journal*, discussed some of his plans for strengthening the *Journal*, starting with getting and maintaining it on schedule in 1960. In one strengthening move, it wa agreed that beginning with the Montre Meeting every effort will be made to pub lish all papers presented within 4 month after the meeting.

Other Actions

In other actions, progress was made to ward implementing the FPRS–NLMA for est products industries "Careers Oppor tunities" program through the 14 Sections. A special committee was appointed to study the Division structure and make recom mendations for the future. Student-chapter development at several universities is un derway; and FPRS has been invited to participate in the World Forestry Congress to be held in Seattle in September.

Regional Nominating Committees

President E. S. Harrar has appointed Re gional Nominating committees for the Northwest and Northeast regions of U.S and Canada. The committees will submit slates of candidates for three-year terms representing the regions on the inter national executive board. Incumbent mem bers are, T. S. Veazey, Jr., Butte, for the Northwest, and Col. J. H. Jenkins, Ottawa for the Northeast.

Named to the nominating committee were: Northwest—R. W. Wellwood, U of British Columbia; G. G. Marra, Wash ington State College; J. B. Granthan Pacific N. W. Range and Forest Experi ment Station; D. L. Haynes, Pack River Lumber Co., and chairman, John D. Ritchie Douglas Fir Plywood Association.

Northeast—Paul H. Graham, Clinic o Wood, Newfane, Vt.; N. A. Norton Penn State U.; E. I. Holmes, Bell Tel ephone Co. of Canada; G. E. Kernohan Northern Wood Preservers, Toronto, and chairman, Fred Simmons, N.E.Forest Ex periment Station, Upper Darby, Pa.

USFPL Three-Day Adhesives Symposium Attracts 100 Top Research and Production Men

At lectern, Dr. R. F. Blomquist, USFPL; left to right: Dr. A. J. Stamm, North Carolina State College; Dr. E. G. Locke, Director, USFPL; C. D. Dosker, Gamble Brothers, Inc.; Fred Werren, USFPL.

Called by the USFPL in cooperation with the National Lumber Manufacturers Association, the symposium attracted men from all parts of the United States.

Group calls for stepped-up research to solve problems and develop more effective glues and gluing processes. Interchange of ideas resulted in 11-point program of recommendations to wood industry.

WHAT GLUES WILL DO FOR THE WOOD PRODUCTS INDUSTRIES in "the fabulous 60's" will be significantly affected by the knowledge and ideas interchanged at a Symposium on Adhesives for the Wood Industry held January 13–15 at the U. S. Forest Products Laboratory, Madison, Wis.

That was the consensus of over 100 top research and production men from all parts of the United States as they concluded the 3-day symposium, with a call for stepped-up research to solve urgent technical problems and develop more effective glues and gluing processes.

The symposium was called by the Laboratory in cooperation with the National Lumber Manufacturers Association to explore new approaches to the solution of industry-wide technical problems.

Stimulates Thinking

"Poor communication between the man with a gluing problem and the man who makes the glue has long been a major stumbling block to better utilization of our wood resources in glued products," said Dr. E. G. Locke, Laboratory Director. "The Laboratory wants to act as a catalyst in bringing manufacturers and users together for an understanding of what is possible now, what is needed, and what may be forthcoming in the future."

Dr. R. F. Blomquist, Head of the Laboratory's Section of Glues and Gluing emphasized that the conference was called to "stimulate thinking on possible new approaches to some of our wood-bonding problems." He emphasized that progress now being made in adhesives and bonding processes for materials outside the wood industry may contribute greatly to the future of the wood industry.

Eleven Recommendations

A committee headed by Dr. Fred F. Wangaard of Yale University School of Forestry, stressed specific areas where research is needed and called upon industry to push development work.

The committee recommended:

1. That the wood industry make a concerted effort to define more clearly the requirements for glues in specific glued-wood products.

2. That adhesive manufacturers continue to familiarize themselves with the changing requirements of the wood industry, and to evaluate new raw materials, such as new polymers and catalyst systems, and new technology developed from other adhesive applications in meeting requirements for applications to wood.

3. That manufacturers of processing equipment take a more active interest in the development of improved equipment for all phases of the gluing process.

4. That there should be closer cooperation between wood-product, glue and equipment manufacturers in contributing to research and development programs needed to produce new and improved wood products.

5. That continued attention be directed toward the development of new and improved glued products of wood and of combinations of wood with other materials in the interest of the economic utilization of our forest resource.

6. That greater attention be directed toward research on the requirements and performance of binders in particle board and other molded wood products. A better understanding is needed of relationships between processing variables and board properties.

7. That fundamental research be undertaken to determine more precisely (a) the nature of the interface between glue and wood surfaces of various species and of modified woods; (b) the interaction of glue and wood as related to the chemical structure of glue components and the nature of wood substance; (c) the rheological properties of the glues themselves and of the final glue line; and (d) the nature of stresses in glued joints under different conditions of joint geometry and various types of loading.

8. That more research be undertaken to understand the fundamental nature of the deterioration of glued joints and of glued-wood products in service. And to develop reliable short-term tests to ascertain the probable permanence of glues in joints on a performance basis.

9. That research be continued to develop improved quality control tests for glued-wood products.

10. That greater effort be made to develop improved specifications for glues and glued-wood products so that quality may be properly safe-guarded without excessive and unrealistic performance requirements.

11. That continued attention be given to the exchange of current views and research findings in the field of new adhesives and glued-wood products. That conferences be held at regular intervals.

In his keynote address, C. D. Dosker, president, Gamble Bros. Inc., Louisville, stressed the value of nationwide conferences in reducing the critical time lag between laboratory development and industrial application. "Gluing smaller pieces, combining species, combining wood with other materials through better gluing processes —are vital to the improved utilization of our timber, if we are to meet the anticipated annual need for 20 billion cubic feet of timber by the year 2,000."

Principles of Wood Gluing

The first session of the symposium was devoted to principles involved in wood gluing. Dr. A. A. Marra, University of Michigan, explained the physical variations of wood caused by the way new fiber is laid down as the tree grows, and how these variations make efficient gluing difficult. Dr. A. J. Stamm, North Carolina State College, showed how the porous nature of wood and its tendency to shrink and swell with moisture changes put added stresses on glued joints, as compared to joints in nonporous metals and plastics.

Dr. Don Brouse, Forest Products Laboratory gluing specialist, reviewed present types of woodworking glues, and John Hess, Technical Director of the Douglas Fir Plywood Association, described the development of self-imposed industry controls to improve the quality of softwood plywood. "Before the markets for plywood can be developed to their fullest potential, an exterior-glue bond in 100 percent of industry production will be essential. No better contribution could be made toward the future of the plywood industry and that of the adhesive industry than research toward that end."

Structural Laminates

R. E. Eby, chief engineer, Rilco Laminated Products, Inc., St. Paul, Minn., considered the question of exterior versus interior quality bonds applied to structural laminates. In many applications, the moisture problem is not critical, and casein glue is still the workhorse.

On the basis of present architectural trends and increased use of glued structural members for bridge stringers, crossarms, transmission towers, and similar products, Eby predicted increased use of exterior adhesives, such as the resorcinol resins for structural laminating. The laminating industry currently uses 5 million pounds of glue (dry basis) annually, and the amount is increasing.

Lumber industry uses of adhesives were brought out by Dr. H. B. McKean, Potlatch Forests, Inc., Lewiston, Idaho. Such uses are primarily edge and end gluing, he said, to produced wide lumber and standard sizes of lumber panels, although two firms have made a concerted effort to market laminated 2 by 4's, and laminated decking is gaining rapid acceptance.

Prefab Housing

Willard Worth, research head for National Homes, Lafayette, Ind., largest producer of prefabricated houses, discussed the tremendous market for adhesives in residential construction. Each house his firm builds now contains about 40 pounds of adhesives, in both structural and nonstructural applications, and new adhesives would increase the figure considerably. Glued assemblies distribute stresses better than do nails, said Worth. The stressed-skin principle of construction used by National Homes was developed by the Forest Products Laboratory and is in wide use by the prefabrication industry.

Particle Board

In discussing particle boards, Dr. G. G. Marra, Washington State University, predicted a great increase in the usage of phenolic resin as particle board enters more markets where durability overrides cost. At present, Marra esitmated, urea resin is used for over 90 percent of all production.

Paper Overlays

"After 7 years of research, low-grade lumber masked with paper overlays is showing real promise," stated B. G. Heebink, Forest Products Laboratory research engineer. Heebink said two types of overlays, resin-impregnated kraft paper and vulcanized fiber, can convert low-quality lumber into high-quality house siding, superior furniture parts, and a host of other products. Costs could be significantly reduced, he predicted, if the present batch process could be converted to the more streamlined roller press operation.

Containers

C. O. Thompson, of The Wooden Box Institute, San Francisco, and Verne Gardner, American Forest Products, Los Angeles, stressed two points: the potential market for adhesives in wood boxes (some 165 million wood boxes and crates were produced in the West in 1959), and the fact that the container industry is an important user of low-grade wood. One-tenth of the lumber cut in the West presently goes into nailed wood containers, Thompson said, and much of this lumber has little other commercial value. Gardner pointedly criticized what he termed excessively strict durability requirements for semi-structural uses where the glued joint would not be subjected to extreme conditions.

Structural Components

"The Douglas Fir Plywood Association is actively promoting the shop and field fabrication of construction components such as beams, trusses, and structural panels of plywood and wood," stated David Countryman, Chief of Applied Research of the Association. The success of these designs depends on effective gluing.

The advent of the structural sandwich in modern construction was discussed by E. W Kuenzi, FPL engineer. "These sandwich panels are highly efficient constructions," said Kuenzi, "because they combine both structural and thermal design characteristics." Such panels depend entirely on adhesives for their integrity. S. E. Susman, Narmco Industries, Inc., San Diego, Calif., discussed sandwich applications in aircraft and emphasized the severe requirements of strength and thermal stability that adhesives are meeting in jet aircraft and missiles, but he pointed out that cost may be an insignificant factor in aircraft applications, if the fastening cannot be made by other methods.

In discussing what modern, high-speed packaging adhesives might offer the wood industry, L. F. Humphrey, H. B. Fuller Co., St. Paul, Minn., observed that "there appears to be no reason why the techniques of high-speed lamination of packaging materials could not be adapted to the manufacture of overlaid panels." Humphrey mentioned speeds up to 500 feet per minute as typical in current laminating operations in the packaging industry.

New Adhesives

E. J. Yaroch and Paul Koller, Minnesota Mining and Manufacturing Co., St. Paul, Minn., described possible wood-bonding applications of new adhesives not now used significantly on wood, such as those based on rubbers, epoxy resins, and other new polymers. The variety of applications for pressure-sensitive tapes was shown by Koller. He pointed to clean removal as the property that differentiates a pressure-sensitive adhesive from "such materials as fly paper goo, chewing gum, and other materials that are sticky but do not have the internal strength to prevent smearing or splitting when removed." He asserted that "a backing can be found to do virtually any kind of job that we have been able to conceive for a tape."

Equipment Needed

"The importance of the machinery manufacturer has not been stressed enough," commented Dr. R. B. Dean, Borden Chemical Co. "Much of our progress is going to depend on our being able to show these manufacturers what we would like to accomplish, and induce them to do the equipment development work." As an example of the type of thinking that may be needed, Dean proposed a machine that would "shoot special toothpick-like particles into particle board during layup" to improve its directional properties and stability.

Chemistry of Adhesives

Dr. George Kitazawa, also of Borden, suggested that more study be given to the idea of stereo-regulated or oriented polymers. "In our present adhesives, the points of chemical attachment to wood are purely at random, and the active chemical sites available may not be effectively used," he said. "There is very promising evidence that we can orient these sites and significantly improve bonding efficiency."

Encapsulation

H. J. Eichel, National Cash Register Co., described his firm's encapsulation process. As presently used, dyes are enclosed in tiny capsules 1 micron in diameter on the back of sheets of paper. An impact on the top of the paper, as from a typewriter key, breaks capsules on the reverse side and releases the dye, which then forms an image on a facing sheet. Such capsule-coated paper eliminates the need for carbon paper. A surface coated with encapsulated adhesive, he said, would remain dry to the touch, and could keep reactive components of an adhesive system separated until pressure or heat is applied. Reactive hardeners and catalysts could also be encapsulated and incorporated in base resins for instant release at the proper moment.

Related Studies

Summing up the various needs for research brought out during the conference, Dr. A. A. Marra noted that many of the ideas originated in the nebulous area. He went on to emphasize that there are many related fields that can also contribute much to advances in gluing. "How about the machining of the wood surface?" he asked. "We know that surface profile is important —perhaps modifying the wood surface may do the greatest good in reducing the dollar cost of gluing by cutting down the amount of glue needed to achieve the bond. The rate of loading of the specimen, moisture content of the wood, thickness of the glue line, assembly time—all these are variables that make us wonder at any stage of adhesive development: Where do we really stand?"

NEW PRODUCTS *and Literature*

Big-Wheel Veneer Sorter

The big-wheel veneer sorter eliminates dead-end veneer handling in mills without space for conventional dry chains, and the wheel permits a 100 percent recovery in sorting.

Veneer coming out of the dryer passes under the electrode of a moisture detector and then drops onto the 24-foot wheel where it revolves until it is sorted.

The wheel is constructed of steel and plywood with rod webbing and gearmotor drive. It can be tailored to fit any mill requirements, but generally the 24-foot wheel turning about 3 rpm. corresponds to a dry chain running at 180 fpm.

Laucks Laboratories, 1201 Poplar Place, Seattle 44, Wash., developers of the wheel sorter, have plans, drawings, and photos available for its construction.

Planing Knife Tests On "Cultured Wood"

Many composition boards and particle boards respond to machine tooling much the same as maple, oak, walnut, and other furniture woods.

To determine cutting characteristics of "Cultured Wood," a composition core stock and hardboard used extensively by Kroehler Mfg. Co., Kennametal Inc., compared the efficiency of tungsten carbide planer knives with steel knives. Tests were made on a Greenlee double surfacer.

It was reported the carbide knives upped hourly production more than 200 percent and cut down-time from 115 percent to 31 percent of operating time.

CZC Treated Wood OK'd for Fire Retardancy by St. Louis Building Commission

Because of its fire retardant qualities, wood impregnated with chromated zinc chloride has been approved by the City of St. Louis (Mo.) Building Commission for use in many instances where untreated wood is not satisfactory.

The commission took action after it was demonstrated that flame spread was reduced by 70 percent on wood treated with the chemical. This applies to both yellow pine and Douglas-fir. A 60 percent reduction is sufficient for obtaining building code approval.

A major advantage of fire retardant wood is its ability to maintain structural strength even at extremely high temperatures. The outside of the beam may become charred, but this merely acts as insulation against further damage. Use of treated wood could result in lower construction costs, particularly where large quantities of materials are invloved.

Soderhamn Announces Plant Expansion

When Soderhamn Machine Manufacturing Company opened its American plant in Talladega, Ala. in 1951, long-range plans were laid for expansion as the company grew. Most recent construction work in this program has just been completed, and the new area will be used largely for an assembly department, enabling installation of several new machine tools and employment of additional personnel in existing manufacturing and engineering departments.

NEW 50" 2-COLOR GRAINING PRINTER

Quick facts on the new 916 2-color printer: Handles material up to 50" widths . . . cylinder diameter 16". Also, may be interchanged on the job to handle cylinders of 9" or 12" diameter. Quick change doctor blade, conveyorized feed system, powered by explosion proof electric motor and switch. 2-color register.

Today the Woodworking Industry is offered something new in a modern 2-color graining machine. It's the Roto Finishing System's advanced model No. 916 . . . the result of close cooperation between machine manufacturing and needs of industry. Sturdily built, amply powered, the 916 handles any receptive surface . . . wood, plywood, composition board, paper or metal. Conveyorized feeds speed handling at variable rates up to 100 ft. per minute. Printing cylinders may reproduce any desired wood or other pattern in flawless facsimile on the printed surface. Finishes lower grade of material to high quality finish, thus increasing its value and market potential.

Roto Finishing Systems produces 13 different graining and coating machines, equipment and cylinders for the woodworking industry. Write now for further information.

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Rolling Chopper For Cull Growth

A new single drum rolling chopper developed by Fleco Corp., is claimed to be fast, economical method of killing undesirable growth up to 6 inches in diameter. Smaller undergrowth is chopped completely, while larger growth is cut and fractured to enable sap to drain out, killing the vegetation. The new chopper should be of interest to pulp and paper firms in reforestation projects. Small hardwoods can be eradicated, planted trees can be thinned and an excellent seed bed prepared for future plantings. Additional information can be obtained by writing Fleco Corp., P.O. Box 2370, Jacksonville, Fla.

Sixth Northeastern Logger's Congress

The program for the Sixth Northeastern Loggers' Congress is virtually complete, according to Fred C. Simmons of the Northeastern Forest Experiment Station, Upper Darby, Pa., General Program Chairman. The Congress will be held at the Hotel Hamilton, Utica, N. Y., April 20–22, 1960.

Into the three days will be crowded a big equipment show, three discussion sessions on the subject "Transport of Logs and Wood," the Loggers' Banquet with a nationally-known speaker, a "Small Sawmill Clinic," and open-house visits at a number of progressive wood-using industries. The annual business meeting of the Northeastern Loggers Association will be held on the evening of the first day. There will also be a program of events for the ladies attending.

Registration blanks for the Congress, and hotel reservation requests, can be secured from the offices of the Northeastern Loggers Association, Old Forge, N. Y.

NAMES in the NEWS

Benson H. Paul, veteran forest products technologist, recently retired from the U. S. Forest Products Laboratory, Madison, Wis. His 41 decades of work have strongly influenced the development of scientific methods for growing better wood in trees. Research he initiated is the foundation for much of the genetics and environmental work now going on around the world, and his findings have been published in approximately 150 reports and articles. A charter member of FPRS, Mr. Paul will make his home in Madison.

Paul

Tomford

Smith

William J. Tomford was recently appointed general sales manager of Fan Air Systems, according to an announcement by Carlton Smith, Fan Air president. Mr. Tomford, a graduate of the Univ. of Missouri and a member of FPRS, has engineering and consulting experience in practically every phase of the lumber and woodworking industry. Other Fan Air officers include: **Carlton Smith,** President; **Abe Lemsky,** Vice-president, and **T. J. O'Brien,** secretary-treasurer.

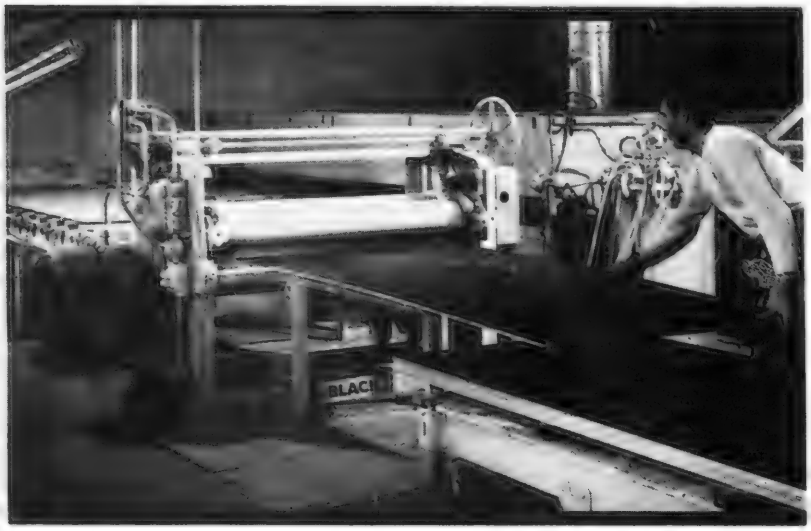
Lou Growney, industrial development engineer, Pacific Power & Light Co., Portland, member of the Inland Empire Section, was recently elected president of the Raw Materials Survey Board.

An article by **John Reno,** Utilization Director of the Pacific Lumber Co., has been given wide distribution by the **Canadian Lumbermen's Association.** Mr. Reno reports that a half million reprints of his article "Wood vs. Aluminum" have been distributed by the CLA in both French and English.

Professor Aubrey E. Wylie, Department of Forest Products, Michigan State University, will spend 6 months at the Institute of Forestry, College of Agriculture in Columbia, where he will instruct in forest products and supervise installation of a small circular sawmill, under sponsorship of the Kellogg Foundation.

H. H. Holliday, Orchard Nebraska, was recently appointed plant inspector and laboratory assistant for the Hardwood Plywood Institute. Mr. Holliday, a recent graduate of Colorado State. Univ. and a member of FPRS, will cover the East Coast.

Black Brothers heavy duty roller coaters apply paints, lacquers, finishes, sealers, sizes, varnishes, stains, waxes, fillers, protective coatings, base coats, drawing compounds and other coatings to flat work such as wood, metal, plywood, composition board, hardwood, plastic, cardboard, cement board, etc.



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72 NEW OR TRANSFER MEMBERS IN JANUARY

Section Officers Please Take Note. We are going to publish each month all of the NEW or Transferred-into-the-Section Members. Please adjust your records, and gear for the most concerted New Membership activity in FPRS history!

CAROLINA–CHESAPEAKE

Charle Barrington, Charcoal Industries, Inc., Conway, South Carolina.
E. Carroll, Route 7, Box 342–M, Roanoke, Virginia.
E. Crawford, Gray Products Co., Inc., Waverly, Virginia.
ert B. Hicks, 1434 Futrelle St., High Point, N. C.
E. Hillard, Food Machinery & Chemical Corp, P. O. Box 1616, Baltimore 3, Maryland.
bert A. Holcombe, Timber Engineering Company 1319-18th Street, N. W., Washington D. C.
ard D. Lane, 4433 1st St. S., Arlington 4, Virginia.
rold McGee, Trustee, 622 Manhasset Road, Charlotte 3, North Carolina.
n F. Shanklin, Staff Asst., Office of the Sec., Interior Bldg., Dept. of the Interior, Washington 25, D. C.
is C. Sproull, Director of Research & Development, 212 Ross Road, Richmond 29, Virginia.

EASTERN CANADIAN

Arthur E. Fick, Box 309, Simcoe, Ontario.
R. Ward Peterson, Forest Products Laboratory, Montreal Road, Ottawa 2, Ontario.

INLAND EMPIRE

Biles-Coleman Lbr. Co., Attn: R. L. McMett, Pres., Omak, Wash.
Carl Burnard, P. O. Box 386, Forest Grove, Oregon.
Adrian D. Swensen, Jacks Trailer Court, 609 N. E. Broadway, Lewiston, Mont.

MIDSOUTH

Ward Archer, Archer & Woodbury, Inc., Du-Pont Bldg., Memphis 3, Tenn.
David T. Armstrong, Sharon Rd., Canton, Mississippi.
Robert G. Baer, 1207 Bertnea, Houston 5, Texas.
Arthur F. Fulmer, 260 Monroe Ave., Memphis, Tennessee.
James R. Gosney, Harbor Plywood Corp., 705 Corinne Ave., Memphis, Tenn.
Arthur Halle, Owens-Illinois, 4605 Minden Road, Memphis 11, Tenn.
William T. Hawkins, P. O. Box 20, Koppers Co., Inc., Texarkana, Texas.
Paul F. Hursey, Tremont Lumber Co., Joyce, Louisiana.
Virgil Kruel, Jefferson City Cabinet Co., Jefferson City, Tennessee.
Roy Wendt, 8506 Eustis Ave., Dallas 18, Texas.
Abbott Widdicombe, William L. Johnson Co. Inc., 1719 E. Broadway, West Memphis, Arkansas.

MIDWEST

Paul S. Byrne, Jr., 2119 Churchill St., Chicago 47, Ill.
Mark Forrestal, 289 Jeffrey Lane, Northfield, Illinois.
William H. Rusch, 5001 University Ave., Madison, Wisconsin.
Francis A. Lawrence, 8100 W. Lancaster Ave., Milwaukee 18, Wis.
Alan T. Mann, 185 North Wabash, Chicago 1, Illinois.
John E. Nohren, Jr., 7720 N. Lehigh Ave., Niles 48, Ill.
George C. Romeiser, American Walnut Manufacturer's Assoc., 666 Lake Shore Drive, Chicago 11, Ill.
Bernard H. Shunk, 1324 West Truman Road, Independence, Mo.
Julius P. Steindler, Engis Equipment Co., 431 S. Dearborn St., Chicago 5, Ill.
Joseph W. Thiel, 984 S. Myrtle, Kankakee, Ill.

NORTHEAST

John T. Clarke, c/o West Virginia Pulp and Paper Co., Tyrone, Pennsylvania.
W. Graham, Dir. of Engr., The Porter-Cable Machine Co., 700 Marcellus St., P. O. Box 1275, Syracuse 1, N. Y.
ichard D. Green, Last Mfg. Assn., Rm. 904-80 Federal St., Boston 10, Mass.
Bradford Holmes, 4440 State Road, Drexel Hill, Pa.
Kaplan Furniture Co., Atten. Simon Kaplan, 574 Boston Ave., Medford 55, Mass.
George T. Overholt, Jr., 161 East Forty-second Street, New York 17, New York.
R. G. Plunkett, 271 North Ave., New Rochelle, New York.

NORTHERN CALIFORNIA

Charles Harrison Roeth, 101 Redwood Products, Box 1001, Willitz, Calif.
William G. Padgham, 162 Hatona Drive, Santa Rosa, California.
Robert L. Ray, 400 Vichy Hills Drive, Ukiah, California.
E. W. Thrasher, P. O. Box 97, Calpella, Calif.

PACIFIC NORTHWEST

Charles Bernert, 1331 Brown Ave., Roseburg, Oregon.
F. E. Brauns, 5537 Parker Avenue, Victoria, B. C., Canada.
H. B. Carswell, Spear & Packson B. C. & Ltd., 6700 Rumble St., S. Burnaby, Vancouver, B. C.
David E. Isaacson, 1627 Carter Lane, Springfield, Oregon.
J. W. Klein, Longview Fibre Co., Longview, Washington.
A. C. Knauss, 15311 S. E. Meadowlark Lane, Portland 22, Oregon.
Dr. E. L. Lovell, Olympic Research Division, Rayonier Incorporated, Shelton, Wash.
Mr. Frederick F. Nord, 4007 W. Walker St., Seattle 16, Wash.
Henry G. Reents, International Paper Co., Long-Bell Div. Vaughn Branch, P. O. Box 308, Veneta, Oregon.
William Swindells, Jr., Williamette Valley Lumber Co., Dallas, Oregon.

PACIFIC SOUTHWEST

Earl L. Barnett, Lebanite Products Co., 2700 Carrier Ave., Los Angeles 22, Calif.
Donald Bellamy, Neiman-Reed Lumber Co., Inc., 13301 Burbank Blvd., Van Nuys, Calif.
Tom Bird, Box 1001, Sacramento, Calif.
James Carlile, Lebanite Products Co., 2700 Carrier Ave., Los Angeles 22, Calif.
Mr. James E. Carr, Waste King Corporation, 3300 East 50th St., Los Angeles 58, Calif.
Duane Eckard, Lebanite Products Co., 2700 Carrier Ave., Los Angeles 22, Calif.
E. E. Graham, Durez Plastics Div., Hooker Chemical Corporation, 6277 E. Slauson Ave., Los Angeles 22, Calif.
Merit Products, Inc., Attn: Aleck Block, 3691 Lenawee Ave., Los Angeles, Calif.
Robert M. Neiman, Neiman-Reed Lumber Co., Inc., 13301 Burbank Blvd., Van Nuys, Calif.
George B. Petty, Lebanite Products Co., 2700 Carrier Ave., Los Angeles 22, Calif.
Jerry Smith, Neiman-Reed Lumber Co., Inc., 13301 Burbank Blvd., Van Nuys, Calif.

SOUTHEASTERN

J. H. Eddy, Kaul Trustees, First Natl. Bldg., Birmingham, Ala.
Robert W. Harding, 1710-11 Street, Albany, Ga.
Walter H. Zingelmann, Jr., 8439 Cresthill Ave., Cresthill Gardens, Savannah, Georgia.

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FPRS FOREST PRODUCTS JOURNAL
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Bombardier Processing Unit converts whole trees into 4-foot bolts (Photos by R. W. Upton, Editor, Woodlands Review, Pulp and Paper Magazine of Canada.)

Feller Buncher fells trees and transports them to Unit where they are limbed, slashed, and conveyed to pallets.

AWAKENED INTEREST CREATES REAL

Progress in Logging – 1959

L. N. ERICKSEN
Chairman, FPRS Logging Division

Giving new methods a chance has paid off with remote control of mobile equipment, radio communications, the use of aircraft, and new designs of tractors, skidders, and loaders.

NATIONALLY, THE LOGGING industry is going through a variety of changes in equipment and methods that would have hardly been considered seriously a few years ago. Their success is due partly to developments in machine and equipment design. Also responsible, however, is an awakening of interest by logging engineers and industry managers in the possibilities of new equipment and the willingness and desire to give new methods a chance to prove themselves. We have taken advantage of developments in other fields and have either taken over equipment and methods or adapted them to logging needs by making necessary changes.

Developments in different parts of the country as summarized below by members of the logging committee present some of the interesting highlights.

Eastern Canada

The logging industry in Canada during the year 1959 was active, with new developments in machinery and methods highlighting the picture. Gaining steadily since the recession of a few years ago, and with labor becoming increasingly competitive in Canada's industrial expansion, mechanization appears to be a predominant trend in the industry.

In this regard, a logging field meeting was held at Baie Comeau, Quebec, on August 4, 5 and 6, where over 40 pieces of new equipment were on display. Perhaps one of the most interesting single pieces of equipment was the Bombardier Processing Unit. Consisting of a limbing tool, cable conveyor, slasher and slash disposal unit, the machine receives whole trees which emerge onto truck pallets as 4-foot bolts. This company has designed a skidding vehicle—the Bombardier HDW Muskeg which was also demonstrated— to be used in conjunction with the Processing unit. Also on display were two new portable barking machines designed to travel into the woods. The Cambio barker was mounted on a Massey–Ferguson 65 tractor, while the Ingersoll–Rand machine was mounted on a Jeep. A report of the meeting, including many photographs, is available from the Pulp and Paper Magazine of Canada.

Research in logging was also active on a number of fronts. The Ottawa Laboratory, Forest Products Laboratories of Canada, continued with project work on harvesting and conversion studies, as well as in the field of log grading. It may be of interest to note that members of the FPLC staff gave the first log grading demonstration (hardwoods) in Canada during the summer, at Pembroke, Ontario. Also of interest is the work carried out by Louis–Jean Lussier, of the Quebec North Shore Paper Company, on Forest Operational Research. Mr. Lussier has, essentially, applied the principles of statistical control methods to the logging industry, where, through the use on control charts, all phases of logging can be better planned and carried out. A partial report of this work appeared in the June issue of the Forest Products Journal.

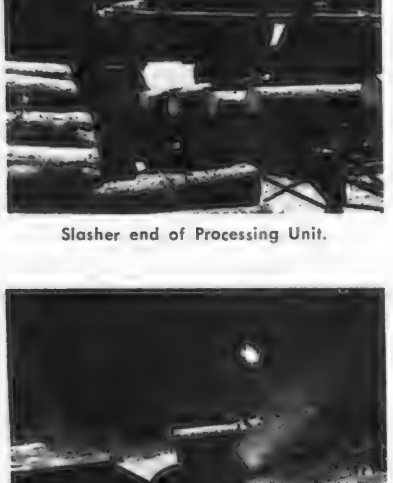
Another item, although still in the very early experimental stage, but which has caught the eye of the industry, is the possibility of logging with helicopters. Dr. Dean Rodgers, of the Consolidated Paper Company, presented an interesting and thoroughly thought-out proposal of this kind to the Annual Meeting of the Canadian

The Author: Leyden Ericksen graduated from the University of Minnesota. He has been associated with the U. S. FPL, Western Electric, NLMA, and the Western Pine Association. He is now chief of the Forest Utilization Research Division at the Pacific Southwest Forest and Range Experiment Station, Berkeley, Calif.

[1] Members of the Technical Committee of the Logging Division who contributed to this report include: J. A. Doyle, Forest Products Laboratory, Ottawa, Canada; Fred Simmons, Northeastern Forest Experiment Station, Upper Darby, Penn.; R. O. Gustafson, Timberlands Division, West Virginia Pulp & Paper, Winnsboro, South Carolina; Robert W. Olin, Potlatch Forests, Inc., Lewiston, Idaho; and George Stenzel, College of Forestry, Univ. of Washington, Seattle, Wash.

Trees are winched on cableway to limber.

Slasher end of Processing Unit.



Chipper converts limbs to sawdust.

Muskeg HWD skids tree-length logs.

Meetings of interest to the logging industry are as follows:

Woodlands Section of the Canadian Pulp and Paper Association, Annual Meeting, Montreal—March

Canadian Lumbermen's Association, Annual Meeting, Montreal—February

Logging Field Meeting, Woodlands Section, Canadian Pulp and Paper Assn., Baie Comeau, P.Q.—August

Canadian Institute of Forestry, Annual Meeting, Price George, B.C. —October

Ontario

Mr. William E. McGraw, Roddis Lumber & Veneer Company of Canada, Sault Ste. Marie suggests that the principal development in northern Ontario is the trend toward the use of smaller tractors for skidding hardwood logs in summer and fall work. Improved models in the small tractors are replacing some of the larger tractors formerly used.

Lighter models, some with rubber tracks, are being used in pulpwood logging and are skidding sawlogs with some success.

It appears that the high cost of larger standard makes of tractors is forcing smaller jobbers into buying smaller and newer equipment for skidding, while retaining their larger equipment for road building.

Northeast

In transporting logs and wood from stump to roadside the four-wheel-drive, four-wheel-steer rubber-tired tractor is now pretty well established on larger operations. In most cases crawler tractors are still used back in the woods to bunch the loads, and then the wheeled vehicle hauls the bunches to the landing over cheaply constructed woods roads. In many cases, these wheeled skidding machines have eliminated the necessity for building any truck roads into the woods. The wheeled tractors haul the tree lengths, over distances as great as three miles, to established public roads.

Many of our smaller operators have been compelled to forego the economies offered by these wheeled vehicles, however. They can only afford to have one machine on the job, and the crawler can operate in many places where the wheeled machine would bog down. Now a Canadian manufacturer has come up with a skidding vehicle that combines many of the advantages of the wheeled skidding tractor and the crawler track machine. This has evolved from the snowmobile, and is called a muskeg tractor. It has four sets of rubber-tired wheels on each side, around which runs a belt-type track of nylon and rubber, with curved spring-steel grousers over the wheels. Traction is provided by a special rubber and nylon sprocket near the front of the machine.

Two models of these muskeg tractors are available, one weighing about 5,000 pounds, and the other about 8,000 pounds. Each model is available in two different types. One type has a mast and swinging boom mounted on the back of the machine, and pulls a log trailer which is also mounted on track-equipped rubber-tired wheels. The boom is used for skidding-in the loads and loading the trailer. Then the machine pulls the load through bog holes, over rocks and stumps, and up slopes as steep as 45 percent to the landing. The other model has a tilting steel platform on the rear, with an upright fence at the front which has a wire rope fairlead mounted at the top.

In assembling the load the platform is tilted up so that the fairlead is elevated, and the trailing rear edge of the platform forms an anchor for the machine. Bundles of pulpwood can be winched onto the platform, which is then lowered so that it rests on the frame of the machine. When tree length logs are being hauled, only the

Lumbermen's Association. An actual field test, employing a Sikorski S–55, was carried out on the limits of the Anglo–Canadian Pulp and Paper Company. The results were not too favorable, it must be admitted. However, the pay load of this machine was about 1/5 of those actually proposed for logging purposes. Moreover, the test was carried out for pulpwood, while the proposals made by Mr. Rodgers were based on the extraction of white and red pine logs.

Radio-controlled skid reeling in logs. (Photos courtesy Fred Simmons)

Loading with radio-controlled skidder.

front end of the tree length rests on the platform. In either type the smaller model machine is capable of hauling a cord of pulpwood or about 500 board feet of logs; the larger model can handle two cords, or 1,000 board feet of tree-length logs.

These machines are proving to be very useful, not only for use in deep snow and swamps, but also on steep and rocky northern hillsides. The first cost is only about two-thirds of that of a crawler tractor of comparable capacity. So far they are standing up astoundingly well in very rough use, and improvements are being made that promise to make them even more durable. An assembly plant for these machines has been established at Lancaster, N. H.

Major developments have also taken place in equipment for loading logs and wood. Modern thin grapples have practically replaced tongs and dogs in handling logs with revolving boom cranes. The grapples, of course, do much less damage to the products being handled, and since they are mechanically or hydraulically actuated, they usually make it possible to dispense with the man on the ground and also the one on the truck. This is an important safety measure, since these were both highly dangerous jobs.

Recently a radio-controlled skidder and loader has been attracting much attention in eastern Massachusetts. The skidder is mounted on a truck chassis, and comprises a winch with the cable running up a mast and out to the tip of a swinging boom, behind the cab. A radio receiver, tuned to the Citizen's band, is mounted in the cab and operates the winch controls. The operator puts the winch in free spooling, and then hauls the logs tongs out into the wood, with the walkie-talkie radio transmitter on his back. When the tongs are attached to a log, which may be as much as 300 feet away, he punches a control botton at his belt, and the winch starts reeling in the log. The operator walks along behind. If the log hangs up behind a root or stump, another punch on the control button stops the winch, the log is rolled free, and the reeling-in operation is started up again. This same unit is used in loading the assembled logs on the same or another truck.

Much loading and handling is also done with tractors, both crawler-track and rubber-tired versions, equipped with hydraulically-operated clamping forks on their front ends. These highly-maneuverable machines are used both at the landings in the woods and the receiving yards at the mills. Some of those at the latter locations are big enough to pick up whole truck loads of logs at one bite.

Southeast

Strong markets for all timber products resulted in increased logging activity during 1959, but record breaking rains seriously hampered operations. This caused heavy logging pressure on the more accessible timber and on the drier sites. A probable sag in the market has been prevented by the inability of loggers to produce timber due to wet ground conditions.

The relatively small size of most tracts of timber is a deterrent to the development of efficient, large scale logging operations. All but a few of the contract loggers—and nearly all logging is done on contract—are small operators with a minimum of equipment. Improvements in their operations and equipment must be cheap and simple. Notable advancements for these operators have been larger tires for skidding sulkies; converted truck-skidders of various types with high clearance, large tires, altered transmissions, and perhaps four wheel drive; and the development of roadside pick-up service for pallet loads of wood.

The development and testing of special purpose machines has continued with some degree of success. Trials of the Michigan and Pettibone–Mulliken rubber tired skidders have brought favorable comment. A few heel-boom loaders and front end loaders have come into use and special unloading machines such as the LeTourneau log stackers are playing a part on the few large operations. Such improved equipment has a place on the best of the large logging jobs under today's conditions. The more revolutionary harvesting machines being developed are suited for special conditions and probably different types of operations that those which are standard today.

Additional long length and tree length logging is being done where the timber warrants. The savings on these jobs is considerable and some few large contractors are developing.

The rapid increase in chipping installations has brought better utilization in the woods. More of the tree is brought in, especially in tree length logging, and that portion not suitable for lumber is chipped. Trees are being limbed with the one-man chain saw.

Many people are working at improving logging equipment and techniques in the South and progress is apparent. Widespread and spectacular changes are unlikely due to the relative size of the timber, timber tracts and operators.

Inland Empire

Telephone System for Truck Log-Scalers: It is the practice in central Idaho regions to scale logs as they are loaded on trucks, in transit at a scaling station, or at the landings where they are unloaded. This avoids double scaling crews and presents other favorable operating characteristics, but does provide a real problem for scalers.

Two scalers are required to scale truck loads of double length—32′ to 42′—logs, or a man working each end. While working, these two scalers kept shouting back and forth the identity of the logs they were scaling and the scale they were taking. When the

logs were frosty and covered with snow, or voices failed to carry in the presence of other machines it was almost impossible to coordinate the efforts of the two scalers.

The Communications Engineering Department of Potlatch Forests, Inc., tackled the problem, and eventually came up with an acceptable plan. A conventional telephone operator's headset and a lightweight mouthpiece were attached to each scaler's hard hat or used the conventional head clamp for the telephone set. This was connected by a flexible cord through a box having a spring-wound reel and a battery for operating the headset. Thus, with the slight inconvenience of the cord and the headset, the two men could inter-communicate by phone with a minimum of effort and error and have both hands free. When they finished a job the spring-retracting reel would wind up the cords and the headsets could be placed in a cavity in the battery box. Thus, the entire unit moved to the next job with a package the size of a small suitcase.

More costly mobile radio sets were given consideration and probably would have served equally as well, but their initial cost and the cost of operation would have been much greater as well as tieing up a critical radio channel for this routine service. Several scalers operating in the same area would interere with each other.

With the telephone that is rugged and relatively trouble free, a crew of scalers can scale 300,000 board feet in small logs as a day's work and find that they still have voices and quiet tempers at the end of a busy day—quite in contrast with previous practice.

Short Log Tandem Trailers: It has become necessary to haul short sixteen-foot logs on off-highway type trucks to river landings where they are decked for spring log drives in the Clearwater region of Idaho. It has been the practice to use smaller trucks with semi-trailers with only about 5,000 to 6,000 board feet of scale that could be busheled onto one reasonable truck load. Tandem trailers had been considered impractical due to the rugged terrain and the short radius curves.

First experimental tandem trailers were made from double axle semi-trailers and rigidly connected to the truck as a semi-trailer. Double bolsters were mounted on the semi-trailer frame. Thus, two loads of short logs could be hauled. The success of this trial led to experimentation with typical tandem trailers of the type used in hauling lumber on open highways, rigged especially for short logs. These have been found to work equally as well and have presented no unreasonable problems.

Ten thousand feet per trip can now be hauled by this arrangement with a very slight improvement in the caliber of roads over which the loads are hauled but effecting definite economy of operation.

Helicopters in Logging: It is very interesting to note the many public restatements of the helicopter material presented at FPRS in Madison in 1958. When repeated in the Northwest area, air-minded loggers seemed to have a more true perspective of the potential of helicopters as a weight lifting device and it accelerated their thoughts. I am sure this series of papers spurred constructive and forward thinking in helicopters in the Pacific Northwest, and is probably an item that could be repeated in the not to distant future by the Logging Committee looking toward research in this field.

In the Inland Empire, one contractor logger operating in very rough terrain of the Bitterroot Mountain region, operates a helicopter as a part of his logging job. This aircraft is not fully justified by the logging operations nor is its time fully utilized. Therefore, it is available on nominal rental rates to others concerned in the industry. Thus, in satisfying his individual requirements for helicopter service, he also furnishes a community benefit to the industry. It is recognized that this in a unique situation where such an open-minded attitude exists with a progressive logger.

The most valuable logging uses are those of making preliminary surveys for logging to provide an overall logging plan compatible with terrain, timber stands and equipment. Road layout is easily accomplished with the use of contour maps as the terrain is actually flown so impediments visible from the air can be determined and the practicality of the preliminary road layout visually determined. Ground surveys then require a minimum of time for relocation and adjustment.

In the logging operation the radio equipped helicopter serves the contractor as a supervisor's vehicle, especially when he may have two or more jobs widely separated without cross country access roads. With this equipment he can maintain supervision on both jobs with a very minimum of time and effort. It is used frequently to expedite the movement of parts or repairmen to disabled machines in remote areas. It is an emergency vehicle to move injured or ill men from the remote areas into hospitals for medical attention at a very minimum of time, thus boosting manpower morale within his logging jobs.

Other forest people have used the helicopter on a rental basis to great advantage. Radio stations on mountain tops can be maintained in mid-winter without opening up roads with ten to twelve feet of snow. Many new potentials of fighting fire were developed through its use by forest fire supervisors on the fire lines in actually directing their crews. By a short, few-minute trip over the fire zones, the fire line supervisor could get a bird's eye picture of the total fire and direct their efforts toward control to much greater advantage and safety of crews. Many other possibilities seem to arise in the use of such craft for fighting larger fires.

In terms of public service as a rescue device, the aircraft has been called repeatedly to move injured, lost, ill, or disabled people from remote areas into civilization. One air-minded logger—willing to run the financial risk—has developed good, substantial uses in his own operation by providing aircraft for rental to develop the use in other operations, and has established a very fine public relations approach through his community uses of the helicopter. Thus, a firm foundation is being built for expanded use of rotary wing aircraft in the rugged forest terrain of the Inland Empire.

Pacific Northwest

General Activity: Merging of small companies with large companies continues to take place. In many mergers the fact that the smaller companies own or control stumpage has influenced certain consolidations. Log production in the region is up over last year by approximately 4 percent.

Garrett Tree Farmer: The introduction of a rubber tired four-wheel drive tractor seems to be well received by timber operators logging medium and small sized timber. Aptly named —Tree Farmer—the unit has shown that it can yard at a cost which is very attractive. The Tree Farmer seems to fit the operating conditions of tree farm logging which involve; smaller logs, highly selective cutting, smaller and more scattered stands, conserving soil cover and young growth, and conserving merchantable timber.

The Tree Farmer has been used on several logging shows and according to the manufacturer has established remarkable production levels on both private and Forest Service operations.

The unit has an oscillating front axle which tends to keep all wheels on the ground for traction all the time.

The Tree Farmer has a unique linkage between the front and rear axles which allow a turning radius of 29 inches, a very desirable feature in selective logging. The unit weighs

2640 pounds. From all reports it appears to be the answer to practicing intensive forestry.

The Pugh Ridge Skyline: A gravity cable system using a radio-controlled diesel-powered skyline carriage has been developed for the Pugh Ridge Timber Company of Darrington, Washington, by the Skagit Steel and Iron Works, Sedro-Woolley, Washington. Presently, the system is being used on a Forest Service timber sale in steep country with unstable soil conditions.

Hanger jacks are used to support the skyline and are spaced 1300 to 1700 feet apart. The carriage of the open-face type is constructed in such a manner that rather heavy side hauls are possible up to a distance of 175 feet on each side of the skyline. Maximum side hauls up to 350 feet are possible but are considered to be uneconomical.

The system could be modified for uphill yarding without a major design change.

Strips up to 5000 feet in length have been logged in timber of 70 M board feet per acre. Production of 60 M board feet per day using a six man crew have been achieved and undoubtedly will increase as the crew becomes more experienced.

The radio control is activated by various members of the crew depending upon the location of the carriage; i.e., cutting area or landing.

A snubbing unit incorporating dynamic braking is used to lower the carriage and turn of logs to the landing area.

The unit seems to function very well, transporting large logs with ease. This system may very well be the answer to logging timber growing in steep, broken country where unstable soil conditions are a problem.

Mobile Spar: A new Mobile Spar has been developed consisting of a tubular steel spar which can be either track or truck mounted. Presently, three sizes are available, a 60-foot spar using a ¾-inch mainline, a 90-foot spar using a 1-inch mainline and a 90-foot spar using a 1 ¼-inch mainline.

The spar is raised using a five-stage hydraulic ram together with guyline winches. Guylines are attached to individual hydraulic guyline motors conveniently mounted under the base of the truck- or track-mounted spar and provide individual control of each guyline. A tailgate-type support braces the spar solidly against the ground with hydraulic levelers. It is claimed that the spar can be lowered in ten minutes, moved and raised again, rigged and ready for yarding in two hours or less, exclusive of travel time. There is a double-bullseye fairlead which is mounted on the spar above the guylines and follows the roads around and stays in lead which reduces road changing time.

The 60-foot spar is designed specifically for prelogging and salvage logging and the heavy duty type is designed to handle the heaviest timber in rugged mountainous country.

Improved Methods and Techniques: The log loading operation appears to have benefited greatly by new designs in log grapples. The advantages of grapples over the tongs are particularly pronounced when large high grade logs are loaded or decked. One large plywood concern has gone to the extent of insisting that only grapples be used on high-grade peeler logs logged or purchased by them.

Research and Development Work: Time studies on the Garrett Tree Farmer (a small rubber-tired tractor) are being conducted by Norman Brocard a graduate student in Logging Engineering at the College of Forestry, University of Washington. Considerable field data is being collected on performance, damage to residual trees and soil compaction.

Conferences and Training Sessions: The University of Washington College of Forestry and the Pacific Northwest Loggers Association are the co-sponsors of a Logging Safety Institute which will be held at the College of Forestry, University of Washington on February 4 and 5, 1960.

The prime purpose of the Logging Safety Institute is to carry the message of logging safety to the smaller operators. Included in the program are four main topics each to cover one-half day. The program will cover: Need For Accident Prevention in the Logging Accident Prevention in the Logging Industry, Accidents-Causes and Cures, The How of Accident Preventions, and Organization and Development of an Effective Safety Program. Each half-day session will be headed by a qualified safety supervior who has had wide experience in programs involving Logging Safety.

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AN INTERNATIONAL LOOK AT . . .

Glues and Gluing, 1959

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Progress in adhesives is evolutionary rather than revolutionary . . . this review summarizes new developments in the U. S., Canada, Great Britain, Sweden, Germany, and Japan.

Fig. 1.—Equipment for laminating 2 x 6 boards, 8 feet long, using preheated wood surfaces and phenol-resin film glue. (Courtesy: Washington State University, Institute of Technology.)

WORLD-WIDE INTEREST IN adhesives assures us of continuing developments in new or improved formulations, new techniques and equipment, and new or improved products. This progress tends to be evolutionary rather than revolutionary, but it continues to produce results.

In this year's review no exhaustive attempt has been made to thoroughly examine the literature; rather, the items cited are presented only as indications of some of the interesting new trends that have developed in the past year.

One innovation in this review is the addition of some brief impressions and

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some fairly detailed information on progress in several countries.[2]

Adhesives

It is difficult to get accurate and specific figures on the actual quantity of adhesives used in the woodworking industry in the United States but figures reported by the United States Tariff Commission illustrate the relative amounts of different synthetic resin types produced.

RECENT PRODUCTION OF SYNTHETIC RESIN ADHESIVES[1]

	1957 (1,000 lbs.)	1958 (1,000 lbs.)
Phenolic and other tar acid resins		
Bonding and adhesive resins for plywood	46,887	51,411
Bonding and adhesive resins for laminating (excluding plywood)[2]	69,198	64,386
All other bonding and adhesive uses	51,169	41,364
Urea and melamine resins		
Bondings and adhesive resins for plywood	98,115	100,406
All other bonding and adhesive uses, including laminating	41,054	43,395
Vinyl resins for adhesives (Other than vinyl chloride and copolymers)	41,965	47,994

[1]Quoted in Modern Plastics Encyclopedia for 1960, page 19. Original source, U. S. Tariff Commission.

[2]This category may include resins used in paper and plastic laminates and is probably not limited to wood laminates.

Data are not available to indicate the corresponding amounts of the non-resin adhesives used on a comparable basis.

Production in Other Countries: The amounts of adhesives used in the plywood industry in Canada in 1956 and 1957 are shown below:

	1956 (Pounds)	1957 (Pounds)
Phenolic	53,818,965	51,707,599
Urea	9,371,845	9,029,505
Casein	2,261,929	1,857,509
Vegetable	4,324,419	3,995,467

In 1958, roughly 16 million cubic feet of plywood were handled in Great Britain, of which about 10 percent was produced in Great Britain and 20 percent from the British Commonwealth. Thirty percent was imported from Finland, 20 percent from the Soviet Union, 10 percent from Japan, and 5 percent from Germany. Five percent was unaccounted for. Almost all of the domestic production and that from the Commonwealth was phenolic bonded of high-grade veneers of either tropical hardwoods or Douglas-fir.

Swedish production of plywood was reported to be about 45,000 cubic meters, of which about 15 percent was birch plywood and about 85 percent Scotch pine plywood. About 10 to 15 percent of this production was glued with phenolic resins. The remainder was largely glued with extended urea resins, but some unextended fortified urea resins were also used. A relatively small amount of blood albumen glue was reported in plywood production for packaging purposes.

Information from the various countries included in the present report indicates that the urea resins are the most widely used wood glues in most of the countries. Other types of glues that are still prominent in wood industries in these countries include the phenolic, resorcinol, and melamine resins, the polyvinyl acetate emulsion glues, and the older casein, vegetable, and animal glues. The proportion of urea resin used in Germany and Sweden is apparently much higher than that used in the United States and Canada. Probably one reason for this is that in Germany and the Scandinavian countries a much smaller amount of plywood is made for exterior service. Apparently the British and Swedish put much more emphasis on the use of gap-filling urea resin glues than is typical in the United States. In England, these gap-filling glues gave generally satisfactory service with certain wood products during World War II. In Japan, seven firms are now making various types of resin glues.

Precatalyzed Urea Resins: Although there appears to be very few really new and unusual developments in urea resins for wood gluing, the glue manufacturers apparently continue to modify their basic resins as well as their formulations with catalysts and other components for specific uses. A trend has been reported in the Southeast of the greater use of precatalyzed urea resins, which have good storage but inherent power of reaction under heat and pressure. These were apparently first supplied for particle board binding, but they are expected to be available soon for plywood manufacturing. The manufacturers of such resins claim greater production of plywood with less labor and equipment, presumably because of the time saved in proportioning the catalyst and resin and the mixing. Presumably, however, one would still have to mix in the fillers and extenders for some of these glues. Such precatalyzed resins would have another advantage of reducing errors in mixing in the glue users' plant. Another trend reported in the Southeast is the use of a common catalyst for both hot-pressing and cold-pressing urea resins. This is of particular interest in furniture plants that have a variety of bonding operations, some of which involve hot pressing while others cold pressing with urea resins. The common catalyst system simplifies the mixing of different batches for different uses in the same plant.

Some sources indicate greater effort is being made by glue manufacturers to develop specific formulations of urea resins to be used on certain specific wood species. This is said to be due to problems in gluing certain species that are not related simply to density and the resultant strength of the wood. A similar development of special urea-resin formulations is also underway for bonding of particle board of different species.

Melamine Resins: In the United States, melamine-resin glues appear to be still used primarily in combination with urea resins as fortifiers or modifiers to improve the durability of the urea resins in plywood manufacture, particularly in hardwood plywood. In Germany, the pure melamine resin is reported to be used for making plywood for boats and similar severe service. This is said to be desirable to avoid coloration of the phenolic resins commonly used in this country for plywood for exterior service. In the United States, melamine resins are commonly combined with the urea resin either from the separate resins at the time of use or by spray drying the resins after their initial condensation. Horioka (*1*)[3] reports making copolymers of melamine and urea resin for wood glues.

Recently melamine-modified urea-resin glues have been used more extensively in the United States in the manufacture of doors for limited exterior exposure. Melamine resin is sometimes also added to urea resins for delayed assembly processes. The labor saving involved is said to compensate easily for the added resin cost, and control of the veneer's moisture content is more important in delayed assembly than in immediate assembly processes.

Melamine-resin glues are of considerable interest in gluing fire-retardant plywood from veneers treated with water-soluble salts. Demand for such fire-retardant treated plywood has increased greatly recently, and so has its availability. Further work on gluing processes for such material is needed

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[2] Additional contributions were made by: Dr. Erich Plath, Forschungsinstitut fur Holzwerkstoffen and Holzleime, Karlsrune, Germany; Bertil Thunnel and Arne Wissing, Swedish Forest Products Research Laboratory, Stockholm; R. A. G. Knight, Forest Products Research Laboratory, Princes Risborough, England; and R. W. Peterson, Ottawa Laboratory, Canada.

[3] Numbers in parentheses refer to Literature Cited at the end of this report.

to improve uniformity and reduce cost. Liquid melamine resins and liquid melamine-urea resin glues are under development and may prove to be very useful.

Phenolic Resins: The most recent developments in phenolic resins are the reappearance of phenolic-resin film glues on the West Coast. Phenolic-film glues had largely disappeared in the United States, their use having been limited to a relatively small amount of specialized plywood production involving very thin veneers that were difficult to spread with liquid glues. Recently, one West Coast manufacturer offered a series of phenolic-film glues that are said to have better flow properties than earlier types without being dependent upon the moisture content of the veneer, one of the serious limitations of the earlier film glues in the United States. One new use for these film glues is in a special laminating process involving preheated lumber. The new film glues are also reported to be faster setting than the older versions. Another manufacturer has installed a 60-inch-wide impregnating machine for the manufacture of such film glues. Another development on a laboratory scale involves the impregnation of paper with liquid resin. The wet paper is then directly applied to the wood without drying. It is thought that this would lend itself to automatic layup wherein the wet web could be serpentined on to each veneer as the layup was built up, starting with the bottom layer first. This wet film produces a good bond on very dry veneer.

The foaming of phenolic resins is still under investigation on the West Coast for plywood operations. One plant has operated with a food-foaming type of machine for one spreader for several months. They use a bark-extended phenolic resin glue and report a significant saving in the operation of this process.

The Japaneses claim to have a phenlic resin that is nearly neutral in reaction and has better color stability than the more alkaline phenolic resins commonly used to impregnate paper for both overlays and for hot-press glues.

Transportation of Glues: Liquid phenolic resin glue is being carried in rubber-fabric tubes on flat-bed trucks (2). The truck carries a load of plywood from the northern California mill to San Francisco and returns with a load of glue to the plywood plant. This is said to save $200 in the cost of hauling glue on each trip. The tube is 56 inches wide and 35 feet long, weighing 1,040 pounds empty and 22 tons filled.

Another West Coast glue manufacturer has recently begun shipments of resin glues to woodworking plants in 300-gallon aluminum tanks designed for easy handling with a standard-lift truck[3]. These are used for shipping glue directly from the resin plant to the consumer's plant where the resin may be drawn off as required through valves at the bottom of the tank. After use the tanks are cleaned and returned to the resin plant. These tanks hold the equivalenat of five 55-gallon drums but occupy considerably less space. In addition to the convenience in handling they result in products of higher purity inasmuch as the resins are not contaminated by the ferrous metals of conventional drums. This results in less discoloration of the urea resins, which is particularly important when they are used for edge gluing veneer.

One of the interesting new trends has been the greater efforts by the users to manufacture their own resins for adhesives and for particle board binders. One operator has a resin kettle and other production equipment mounted on a truck that can be transported to the glue user's plant for manufacture of the resin on the plant site. Significant economies are made in the cost of the resin. There is a continued trend reported for some of the West Coast plywood producers to go into this resin manufacturing. Several large companies are making explorations, and some smaller companies are considering forming groups to support their own resin-producing plants. One large West Coast particle board producer has been making all of his own urea resin for the last several years. At least one prominent middle western plant is also making all of their own urea resin and some phenolic resins for plywood production.

Resorcinol Resins: These glues continue to be important in the laminating of timbers for exterior service and for other special applications. Their use is fairly general, but they are used considerably more extensively in the United States than overseas. Investigations continue on a limited scale to develop faster setting glue systems based on resorcinol resins and phenol-resorcinol resins. These generally involve the use of special fast catalysts with more or less conventional resins. It does not appear at present that these special formulations are suitable for general use where fast setting at normal shop temperatures is important. Several chemical companies are currently investigating markets for resorcinol and resorcinol-resin adhesives but no new production has yet been announced for the basic resorcinol.

One West Coast laboratory is reported to be cooperating with a large western lumber producer in developing a lower-cost resorcinol-resin glue that is creating interest in gluing circles throughout the country. Work is continuing in order to bring development to completion at an early date.

Latex—Protein Combinations: Interest seems to continue on combinations of rubber latex and protein glues. This is an example of a current trend towards more attention to combinations of different resins or resin and nonresin components in new adhesives. Such combinations offer compromises between the best properties of each of the two components plus an opportunity to minimize the more serious limitations of either component. In the case of the latex-protein adhesives, this produces a fast-setting adhesive, comparable to the polyvinyl acetate emulsion but with somewhat improved moisture resistance. The use of these protein-latex emulsion systems as room-temperature-curing adhesives is gaining in plants that manufacture flush doors in short cold-press cycles because they produce a somewhat more moisture-resistant bond than do the vinyl emulsions and at a reasonably low cost. These adhesives are also being investigated for use in place of urea resins, and some attention is being given to their possible use in Type I hardwood plywood applications. One typical casein-latex combination is available at about 12 cents a pound for the mixed glue. It can be used with a clamp time of 45 minutes at normal room temperatures, if machining is delayed for a couple of hours after the pressure is removed. The pot life of such a glue is from 4 to 6 hours.

Contact Adhesives: The rubber-base contact adhesives continue to be of interest to woodworkers because of their fast development of initial strength. Originally these adhesives were essentially dispersions of neoprene rubber in organic solvents and were applied to both mating surfaces. After a relatively short drying period to a nontacky state, the two surfaces were brought rapidly and carefully into final position and then pressed under essentially contact pressure. A fairly high initial strength was developed immediately because of the high cohesive strength of the partially dried film. However, the bonds develop additional strength rather slowly over a period of several weeks at room temperature and never appear to reach the high level of strength of the conventional woodworking glues. The level of strength developed is quite adequate, however, for bonding of high-pressure laminates to plywood and other bases for furniture and counter

tops. This type of adhesive has also been adopted for industrial use where the wet adhesive film is rapidly dried under a bank of infrared lamps on a conveyorized system after which the coated parts are rapidly brought together and run through a nip roll to achieve very rapid bonding.

At the present time, there has been some use of these contact cements for bonding skins to doors, including rather large garage doors. The properties of these contact adhesives, including their permanence and resistance to creep and dead loads, are now a subject of considerable experimentation in various laboratories.

More recently neoprene-base contact cements have been made available in water emulsions. These are reasonably resistant to freezing and thawing cycles and no inflammable solvents are involved. Studies are underway in several laboratories to evaluate these new water-base contact adhesives but little data are available at present. Some of the solvent-base contact cements are also used for special gluing problems, such as end banding and edge banding of strips on furniture panels.

Epoxy Resins: Another relatively recent type of adhesive that was developed primarily for metal bonding is the epoxy-resin adhesive. They have some unusual properties, but their cost makes them still somewhat questionable for any standard wood-gluing operation in large volume. The original epoxy-resin adhesives in metal bonding were formulated from a resin condensed from epichlorohydrin and bisphenol with an amine curing agent added in mixing the adhesive. More recently, a wide variety of epoxy resins, with greater reactivity, and a large number of curing agents of both amine and dibasic acids have been under study and development. Little effort has been directed towards formulating adhesives specifically for wood bonding operations, but it is quite likely that several of the formulations already developed for metal bonding and other special operations might be quite applicable for some wood-bonding operations. The principal characteristic of these epoxy-resin adhesives of interest for wood bonding is 100-percent reactivity, without splitting off any volatile byproducts or requiring the use of any liquid solvents which must then be removed in the process of bonding. This results in an adhesive that will set under relatively low pressure and will be quite dimensionally stable after curing. It fact, these epoxy resins have been widely used for potting compounds in the electrical industry, where their dimensional stability in a mass is an important property. These 100-percent-reactive epoxy resins do not require pressure to resist the escape of volatiles during bonding, but bonding pressures are still needed to force the wood surfaces into reasonably close contact and to hold them together until the adhesive develops sufficient strength to resist stresses when the pressure is released. Actually, although the epoxy-resin mixtures are typically quite exothermic with very short pot life in rather small quantities, they are relatively slow setting at room temperature since much of the exothermic heat is immediately dissipated on the wood. Special double-spray nozzle applicator units have been developed for spraying premetered quantities of resin and curing agent. Thus, the adhesive is in effect mixed at the point of application and a reactive system can be used. This technique was developed primarily for the use of epoxy resins for glass-reinforced laminates used in the manufacture of small boats, but it could easily be adapted for use with adhesives for wood bonding. This same technique might be used for other chemically reactive adhesive systems for wood bonding.

Special Formulations: Epoxy-resin adhesives for wood must still be considered specialty items. The trend is towards custom formulation of special epoxy adhesives for difficult bonding problems, particularly for composites of wood with plastics or metals since these adhesives have unusually good bonding properties to a variety of metals and plastics. A one-part epoxy-resin adhesive has recently been announced.

Another related development, which has not yet had any significant application in adhesive bonding, is the recent introduction of resorcinol-diglycidyl ether. This is essentially a monomeric compound of resorcinol and epoxy resin. Actually it is an epoxy resin-forming compound that may be of considerable value in the development of new epoxy resin systems in the future. Its use in adhesives is under investigation.

Of the large number of new polymers being produced by the chemical industry, any of which might potentially be important bases for new wood glues, one type that is receiving considerable attention and research as a new adhesive system are those polymers that are 100-percent reactive and stable in a mass but unstable and chemically reactive when spread as thin films. The best example at the present time is the adhesive based on beta cyanomethylacrylate and introduced by Eastman Kodak Company a year ago. This adhesive has been investigated by several laboratories on a limited scale for potential use in wood bonding, but it does not appear to be particularly promising at the present time, particularly considering its high cost.

Another resin system that continues to receive some attention as an adhesive base is the polyurethane type of resin, produced by the reaction of certain polyesters with di-isocyanates. These are the same resins that are foamed for rubber-like cushioning materials in furniture. In general, they have a strong natural adhesion to a wide variety of surfaces, somewhat like the epoxy resins, but they have not yet received much attention as wood adhesives.

Binders for Particle Board: Urea resins continue to be the most widely used binder for particle board both in this country and overseas (5, 6). These resins are sometimes very similar to those used for plywood gluing but they are also sometimes specially developed for binders of wood waste materials. They are either used with or without added catalyst. A special requirement generally is to have low free-formaldehyde content in order to avoid objectionable odors in the plant process and in the use of the board. The growing interest to broaden the markets for particle board tends to center attention on the use of more durable binders. Phenol resins, because of their good record in exterior-type plywood, are currently considered as most promising.

Bonding Techniques and Equipment

In addition to interesting new adhesives, new bonding techniques and equipment continue to be developed. In general, each new type of adhesive requires somewhat different bonding techniques. Good examples are the contact adhesives that have brought about the use of the nip-roll press instead of the conventional platen presses. Some of the new equipment and techniques for gluing have been summarized by others (7).

One of the most interesting new techniques has been an improved method for laminating timbers with preheated wood and a phenolic-film glue (8). This is an extension of an earlier technique developed for laminating 2 by 4's, 8 feet long, with preheated lumber and liquid glues (9). Key apparatus in the new operation is an experimental beam-laminating press capable of laminating four 2- by 6-inch boards, 8 feet long (Fig. 1). The boards are laid separately on edge, parallel to each other, in the jaws of the press. Three electrically heated plate-type preheaters are then inserted for several minutes between the boards, after which they are withdrawn, and

Fig. 2.—Laminated beams in exposed roof of a restaurant in Englewood, Colorado. (Courtesy: Best Wood Products Co.)

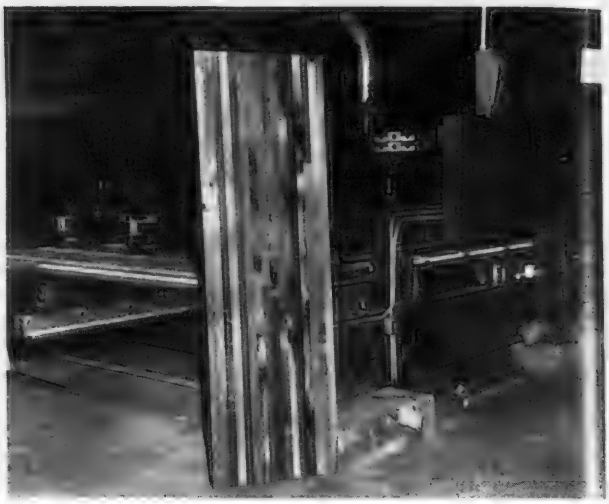

Fig. 3.—Building panels laminated of material unsuitable for use in beams. The size of the panels—26 inches wide, 3¾ inches thick, and 7 feet high—plus the fact they are finished on both exterior and interior surfaces permits speedy erection of buildings. (Courtesy: Best Wood Products Co.)

the resin inserted in film form. The press then closes quickly, moving the boards together under pressure for about a minute and a half to complete the laminating cycle. The new beam press employs a unique system of hydraulic and mechanical devices. The process requires only about 12 pounds of adhesive film per thousand square feet of glue line on a dry basis, compared to the 70 to 100 pounds of liquid adhesive commonly used by conventional laminating processes.

Automation: One new West Coast plywood plant has incorporated several new automation features. The process is built around a 30-opening hot press, which closes simultaneously in all 30 openings. An indexing loader for the press eliminates the need for two men riding an elevator to load the loader itself. Such fast loading and press closing results in an unusually short closed—assembly period for the last panels spread in each press load.

Foamed Glues: The use of foamed glues and foaming equipment in the United States was reported last year. Although foaming of glues for woodworking was first used in Europe before World War II, its use in Europe seems to have been decreasing. Apparently the early necessity for foam glues was the lack of adequate spreading equipment to put a uniform but economical spread on the quality of veneer available. In recent years, the spreading equipment has been much improved in Europe; therefore, the need for foam glues has decreased. It is reported that foam glues still are considered favorably in Finland. A foam-glue process (10), announced last year on the West Coast is still under development in at least one plywood plant, but there is no wide commercial use of the foam glue. Experiments on foaming with urea melamine, phenolic, and modifications of these adhesives have been reported. Apparently one big incentive is the potential cost saving through eliminating waste with these foamed adhesives.

Edge and End Gluing: Vertical glue spreaders are available for special end-banding operations. The Japanese have been experimenting with foam-rubber rolls on spreaders to give lower spreads on fairly smooth veneers. A new process for end gluing of wood veneers was announced (11). The use of quick-closing fire-hose type cold presses continues, particularly for bonding plastic laminates to plywood with polyvinyl acetate emulsions, casein-latex, and contact cements.

Manufacturers continue to develop more efficient and economical equipment and processes for edge-and end-gluing operations. These bonding processes are set up to operate essentially on a continuous basis, particularly for end gluing lumber with finger joints, and may involved either room-temperature curing with fast-setting adhesives or the use of high-frequency heating. Interest continues in end gluing as a good method of utilizing short lengths of lumber (12). At least one new plant has been announced by a major lumber manufacturer to produce edge-and end-glued lumber for stock panels up to 24 feet long and as wide as 54 inches and as thick as 4 inches. This particular process involves high-frequency heating (13). The thinking apparently is to produce large panels that can be later cut into any desired size.

Edge- and end-gluing is becoming of importance also in particle board as a means of making smaller panels into larger ones and to reclaim some of the cutoff pieces of the panels (14). Butt jointing is considered here generally rather than finger jointing.

Some Japanese plywood plants are reported to be using a rather interesting combination of cold pressing followed by hot pressing that does not seem to be typical in this country. A typical plant may have two hot presses and two cold presses of rather small size. They run spreaders for 8 to 10 hours a day, but they run hot presses up to 20 hours a day. A process reported involved cold pressing the freshly spread panels for 2 hours in bundles and then later hot pressing for a conventional period of time. This delayed hot pressing allows time for repairs on panel faces between the removal from the cold press and insertion into the hot press and before the final cure of the glue.

Glued Products

The following summary is intended to offer a few highlights of some of the interesting products currently being produced from wood through modern gluing processes.

The laminating of 2 by 4's and the new process for laminating of large beams by preheating has already been reported (8, 9).

Roof Decking: The variety of new laminated products continues to increase (14) (Fig. 2). One interesting new product is a 3-ply roof deck of softwoods laminated with the individual laminations offset to provide

built-in tongue and groove. This roof decking can be made with one species or a combination of softwood species in lengths up to 16 feet and of nominal 3- and 4-inch thickness and 6- and 8-inch widths. Currently, the gluing is done with a resorcinol-type adhesive cured at high frequency. Advantages of such laminated decking over the conventional solid decking include reduction in the tendency to split and check, and reduction in the tendency of the joints between planks to open up in service since the laminated material is more uniformly dried than the solid material.

Selects Material for the Products: One laminator in the Rocky Mountain area separates the material which is not suitable for beams and produces a variety of other laminated products, such as table tops, counter tops, truck beds, and wall panels. The wall panels (Fig. 3) are made up typically 26 inches wide by 3-¾ inches thick by 7 feet high and are used for houses and other buildings in remote and inaccessible areas where erection time is important. This same laminator, recognizing that he is supplying material for a relatively small geographical area with a fairly uniform climate, uses lumber which has been kiln dried to an average moisture content of 12 percent and then strip piles each layer of lumber in a stack to let it air dry and equalize in moisture content. The average moisture content when glued is about 9 percent, which is believed to result in a more satisfactory product for the Rocky Mountain area.

The British laminated wood industry apparently follows much the same pattern as the United Staes. One specialty reported in English is the laminated wood beam used in subways to carry the shoe that picks up the power from the conductor rail at ground level. Formerly, the beams were of solid wood and gave much trouble, but the laminated beam has proved to be much superior.

A laminating plant in Sweden uses casein for the normal interior uses, but they use a cold-setting phenolic resin when severe service is expected and a resorcinol resin for heavy outdoor conditions.

Molded Plywood: Curved and molded plywood continues to be produced for certain specialty items. The British report considerable interest in molded plywood hulls for sailing dinghies, which are now very popular. These are still produced from shaped or tailored pieces of veneer laid at appropriate angles. Some hulls are bonded under pressure in autoclaves and others are fabricated by a tacking-strip method. The use of specially formulated phenolic- and resorcinol-resin glues is typical here. Curved forms for chair seats and other furniture components in England are commonly made between male and female dies, and the glues, typically urea resins, are cured either with high-frequency or low-voltage heating. Vacuum or vacuum-pressure presses are also popular for this type of application.

One American plant is reported to be studying the manufacture of hollow-core doors in a one-step gluing operation. A large-scale production was actually tried and fair results were reported. The panels are not preglued, but the door is made as a 5-ply unit in one gluing operation. Urea resins are used in this operation. Incentive is a potential cost saving over the conventional process of bonding two previously prepared 3-ply panels to the hollow core in a separate operation.

New Theater Chairs: Another interesting glued product recently produced was a set of 12,000 theater-type chairs for a sports arena. The significant feature of the chair as it concerns glues is the fact that a 0.02-inch rigidized and anodized aluminum sheet was bonded to the outer face of a 7/16-inch-thick birch panel (fig. 4). The birch panel was first glued and formed to an 18-inch radius by conventional hot pressing and completely machined. In the secondary gluing operation, both the cut-to-size aluminum sheet and the outer face of the wood panel were sprayed with a rubber-base contact cement, allowed to air dry for 25 minutes, assembled and sent through pinch rolls. Aluminum was trimmed to the wood outline on a band saw and an anodized aluminum molding was assembled around the side and top edges in a punch press. The anodized treatment for the aluminum produced a sufficiently clean surface to bond directly without any further preparation.

Paper Overlays: Paper-overlaid lumber sheathing in panel form now competes with other sheet materials for the sheathing market in housing. It provides lumber panels in sizes that can be readily handled by the workmen and installed with a minimum amount of labor. The bond between the untreated paper and the lumber is considered to be of somewhat temporary value, and it is commonly made with a protein-blood glue in some sort of a rapid-setting process. One plant in the Southwest uses such a glue with a few seconds' stepwise press and heating cycle. The boards are not edge glued previously. The process is said to be entirely automated.

Fig. 4.—Theatre seats curved back panels of birch to which an anodized aluminum sheet is bonded with a rubber-base adhesive under pinch-roll pressure. (Courtesy: American Seating Co.)

Tests and Specifications

This subject continues to be of great importance throughout the world as new types of adhesives are introduced to the wood industry. It is generally recognized that some of the newer types of adhesives, such as the contact cements and epoxy resins, require somewhat special test procedures to evaluate their properties. The work of a number of groups in this field is important. In the forefront of such development of new test procedures for wood adhesives in the United States is the new Subcommittee X on Wood Adhesives of ASTM Committee D–14. This subcommittee has two groups—one active on the East Coast and Middle West, and one on the West Coast. Such test methods and specifications on glues are of necessity rather directly related to corresponding tests and specifications on the glued wood products.

Interior Plywood: One important development in test methods for glued wood products is the change in the test procedure and requirements for interior-type Douglas-fir plywood announced earlier this year (16). This procedure reduces the size of the test specimen from the conventional 6- by 6-inch square to a 2- by 5-inch specimen, reduces the number of cycles from 10 to 3, and increases the severity of the cycle by requiring a temperature of 100° F. during the drying phase. The new method gives a somewhat more severe test but a more uniform test, and it is more applicable to the use of plywood containing white-pocket veneer.

On an international basis, there is a difference of opinion as to the best types of test procedures for evaluating

Fig. 5.—Portable sonic glue-joint tester developed in Canada for nondestructive tests for defects in glue joints in plywood and other multilayer panels. (Courtesy: Ottawa Forest Products Laboratory)

the quality of glue joints in plywood. The British prefer continuous soaking tests rather than the cyclic wetting and drying tests that are commonly used in this country and in Canada. Most British standards for glues and glued products involve various periods of continuous soaking in either cold water or in boiling water. One British Admiralty specification for gluing of wood for special minesweepers does involve a wetting and drying cycle. The soaking and drying cycles are preferred in this country, and are included in many of the specifications for glued products, primarily because of the mechanical stressing on the glue joint as a result of the dimensional changes of the wood during soaking and subsequent drying. It is recognized that this soaking and drying must be done under reasonably controlled conditions in order to be effective and to have reproducible test results. This is one of the principal reasons for the changes in the new interior-type test for Douglas-fir plywood previously noted. The Germans are also reported to prefer the cyclic tests, such as the boil-cycle test for plywood, rather than the continuous 70-hour boiling test which is used in England. Paper-chromatography tests on the water after 70 hours boiling of plywood specimens indicated excessive wood hydrolysis by this prolonged boiling, according to a German study.

This interest in cyclic soaking and drying tests has resulted in considerable study of automatic methods for conducting these soaking and drying tests according to fixed schedules (17). So far these, tests have been used on an exploratory basis in certain laboratories, but they have not been adopted for routine testing for specification purposes.

Canadian Specifications: Several new specifications and new additions in existing specifications on glues and glued wood products have been recently published or are being prepared by the Canadian Standards Association. A new edition of the Canadian Standards Association Specification for Glued-Laminated Softwood Structural Timbers has been published, seven new wood—adhesives specifications on animal, starch, casein, polyvinyl, urea and phenol and resorcinol adhesives have been completed, a revision of CSA Specification for Hardwood Plywood has been completed, and new specifications are currently in preparation for western softwood plywood, poplar plywood, and for wood doors.

Also in Canada, considerable effort is still being put into the search for better and faster test methods for evaluating glue joints, particularly those in plywood. This work is being spurred by the need for a test for exterior-type bonds in plywood manufactured from species other than western softwoods species, particularly poplar plywood which is now being produced in Canada in large volumes. The problems with evaluating wood failure on plywood shear specimens are accentuated with poplar because of the shallow nature of the wood failure obtained. Thus, the trend is towards the development of accelerated delamination tests for exterior-type bonds in these materials, rather than to use the conventional shear test which requires wood failure estimation as a primary criteria of bond quality. Some attention has also been given in the United States to the possible adoption of delamination measurements after the boil-cycle test for exterior plywood rather than to use the present shear test and wood-failure determination.

English Specifications: In English, specifications on glues and glued products are prepared by committees of specialists convened by the British Standards Institution, and the documents are subject to review either at regular intervals or at the request of the industry concerned. At such a review of British Standard 1203, "Synthetic Resin Adhesives for Plywood" in 1954, the classification system was adopted which linked the type of adhesive with its durability. For example, Type WBP (weather and boilproof) included those glues ". . . . which by systematic tests and by their records in service have proved highly resistant to weather, microorganisms, cold and boiling water, steam and dry heat . . ." Other types are BR (boil resistant), MR (moisture resistant), and INT (interior). These terms have since been incorporated into the allied specification for synthetic resins for assembly work (B.S. 1204: 1956) and in the two plywood specifications (B.S. 1088: 1957; B.S. 1455; 1956).

The British report that phenol, resorcinol, and combinations of these two generally adhesives meet the requirements for Type WBP; melamine and some fortified urea resins meet requirements for Type BR. Urea resins will meet the requirements for Type MR, and polyvinyl acetate, flour-extended ureas, casein, soy, animal, and blood glues are reported to meet the requirements of Type INT. In British specifications, however, classifications are assessed entirely by the kind of test procedure applied, and no mention is made of the chemical type of adhesive.

In 1959, the Swedish authorities began the standardizing of requirements for plywood. Their requirements include standardized construction of plywood from veneers of standardized thickness, and standardization of the quality of gluing in indoor and outdoor plywoods. This standardizing of constructions and quality of plywood has as its immediate purpose the control of the strength properties of the plywood for design purposes.

Quality Control: As the utilization of plywood and other glued products expands, particularly into some of the more severe types of service, the problem of quality control on a continuous basis during production becomes of great importance. This problem naturally focuses attention on the possibility of using nondestructive tests on a more or less continuous basis during production. This is admittedly a very

difficult problem to solve, particularly to develop reliable methods to distinguish between good glue joints and joints of medium or mediocre quality. Some recent progress has been reported for a nondestructive method for detection of blisters in plywood (18). Recent tests of this sonic device in a Douglas-fir plywood plant indicate that a high degree of sensitivity is obtained in spite of the high level of plant noise. A portable version of the device has been developed for detailed inspection of small panels of plywood and other multi-layer materials. Patents covering this development have been applied for in Canada and other countries, and a license to manufacture commercial flaw detectors has been granted to a Canadian firm. This firm is now producing portable units (fig. 5) and is developing of a high-speed automatic industrial model capable of inspecting 400 square feet of plywood per minute.

Specifications and Standards: A major revision is underway on military specification MIL–A–397–B for phenol-resorcinol and melamine-resin glues. Present plans call for two specifications, one for general purpose use (MIL–A–22398) and one for marine service (MIL–A–22397).

The Southern Pine Inspection Bureau is currently developing standards for glued wood products of southern pine.

ASTM Committee D–7 has recently made further changes in the familiar vacuum-pressure test for laminated timbers based on those glued with durable-type glues (19). A cleavage-type test for evaluating strength of wood glue joints has been recently proposed (20).

New Dead-Load Test: Other new test procedures are under consideration in various laboratories, either as research tools or for possible inclusion in subsequent future specifications. One such test is a dead-load test, for evaluation of rubber-base adhesives and other new thermoplastic adhesives that might be subject to deformation or creep under continous loading either from external loads or from the internal stresses on the joints as the result of swelling and shrinkage of the wood from season to season. Current procedures for dead-load tests are essentially modifications of tests already used for evaluation of metal-bonding adhesives.

Other Research

In addition to the extensive research involved in some of the previous developments is described in this review, additional research has been reported that may be of interest to the readers.

Japanese workers (21) have been conducting experiments of a rather basic nature to study the best type of urea resin as a glue for plywood, particularly when pressed at 95° C. They have made a series of urea resins using urea with a tagged carbon atom. At 10-minute intervals, the condensation products are separated by paper chromatography and analyzed through radioactive isotope determinations. The corresponding resins were then used for bonding birch plywood, which was then tested in hot and cold soaking tests. The authors suggest that dimethylol urea contributes to the adhesion forces while methylene-diurea contributes to the cohesive strength of the resin and that secondary addition of urea after the initial urea-formaldehyde condensation improves the glue-joint quality.

Latent Hardeners: Another interesting Japanese study concerned an investigation of different latent hardeners for urea resin glues (22). They reported that a pyridine-monoacetic chloride hardener had a delayed action with the resultant longer pot life at low temperatures and a rapid set at higher temperatures. Also, diammonium imido-sulfonate and pyridine together has latent high waterproof properties and durability. They also suggest that urea added to the urea-formaldehyde resin as a formaldehyde fixer has a delaying action at low temperatures but reduces the durability.

Horioka also studied the effect of adding paraffin wax emulsion to urea-resin adhesives in plywood of lauan and birch (23). He found that, as the wax increased to 20 percent of the urea-formaldehyde resin viscosity decreased, the gel time increased, and that the wax didn't interfere with dry strength, but it reduced the wet strength slightly. Lauan plywood with 10 to 20 percent wax in the glue was reported to have only about one-half to one-third of the water-vapor permeability of the control pieces.

The subject of adhesion continues to be of much interest in the United States. Although adhesion to the conventional domestic species of wood has not been considered a serious problem from a practical standpoint, the wider interest in foreign species and in bonding of wood to a variety of other materials, including metals, plastics, particle board, and hardboard for laminates, has introduced new problems. Most authorities agree that a better basic knowledge of the fundamentals of adhesion would be of great help in understanding the practical solutions to some of these new problems and would reduce to a considerable extent the amount of empirical testing otherwise required to solve such problems.

There have been many review papers of the fundamentals of adhesion in recent years. One rather extensive review has recently been summarized (24).

Marian and coworkers have recently reported on further studies on the effect of surface texture of wood on the resultant glue-joint quality (25).

Mechanisms of Adhesion: Investigators at Massachusetts Institute of Technology have recently announced a breakthrough in the understanding of the mechanisms of adhesion. Their work indicates that low-molecular-weight degradation products at an interface may act as contaminants with low cohesive strength and form parting planes under stress. This results in failure which had been previously thought to be due to actual adhesion failure.

In England, most of the work on adhesion is done by the universities. This work is largely coordinated by a Government committee which is reported with intentions to publish a book some time in 1960 covering the collated results of all this research.

This section is by no means complete and offers only examples of some of the more important developments currently under way in the field of adhesives of interest to the wood industry. One may expect this rate of development and research on adhesives and adhesion to continue at a good rate because of the continually expanding interest in the use of adhesives, not only in the wood industry, but in many allied fields as well.

Survey of Literature

In addition to the list of references cited in the present review, a bibliography of selected articles of interest during 1958 is also appended. This list was compiled by the library staff of the College of Forestry, University of Washington. An additional list by R. A. Currier is on page 130. Their assistance is gratefully acknowledged.

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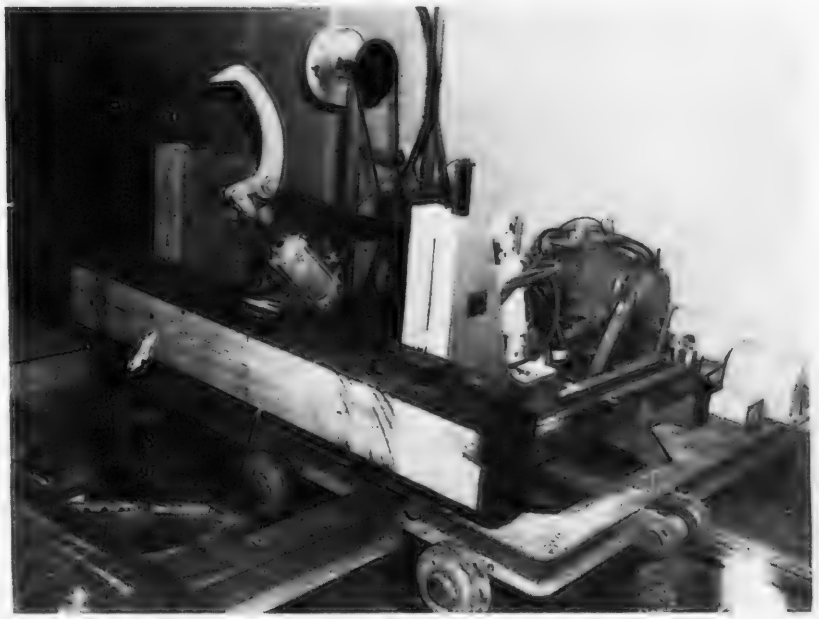
BOOMING ECONOMY BOOSTS

Lumber Manufacturing in 1959

MILTON H. MATER
Chairman, FPRS Lumber Manufacturing Division

The fifties brought riderless carriages, automatic log decks, debarking, chipping, lift trucks, and other improvements. Forecast for the "fabulous sixties" . . . more automation, more packaging, more research, more utilization.



Stud mills are receiving increasing attention throughout the United States to solve many regional problems.

TRUE TO LAST YEAR'S predictions 1959 proved to be a banner year for the lumber industry. Almost all the lumber regions in the United States and Canada reported good markets and near record production.

The lumber market in Alabama and Georgia, for instance, is claimed to be the best in a decade. According to A. W. Skoropat, Chairman of the Alabama, Georgia and Mississippi area and a contributor to this report, "Practically all the production in Georgia goes into the lumber market of Florida, which is at present at its all time high. Today it is doubtful that a buyer could find over a few loads of dry lumber available for immediate shipment in the state of Georgia." Eastern Canada expects the final reports of lumber production in 1959 to exceed that of 1958. The interior region of B. C. estimates that the 1959 volume will exceed 1958. However, the Canadian Douglas Fir Region suffered a serious production setback when all western operations were strike bound for ten weeks in mid summer. Pacific Northwest fir and hardwood mills reported an increase, though fir production was still about 3 percent below the 5 year average. The Lake States promises a substantial increase in lumber production in 1959. Siegfried Tolle, Chairman of the Northeast Hardwood Region, reports that lumber is up, stumpage is high and most mills are suffering from an acute log shortage.

Technical Advances Rapid During The Year

A number of interesting new technical advances were made during the year. In the Southeast, the installation of sparse tooth saws in the edgers, circular gangs and headrigs for the direct production of saw chips was being watched by lumbermen. Wells–Griffin Lumber Company, Valdosta, Georgia has three installations using these saws and reports an increase of approximately 40 percent to 50 percent in the amount of saleable chips.

Increased residue utilization was spotlighted in many regions. Accelerated decomposition of sawdust for horticultural uses was under trial by a Canadian Douglas Fir mill. Northwest hardwood mills found their sawdust in demand in many areas for meat curing and mulch. Northeastern hardwood mills have shown great interest in bark as mulch and sawdust for barn bedding. The Vermont Industrial Development Organization is pushing bark utilization due to increase in use of barkers.

In California two large mills are profitably processing bark for resale for horticultural purposes and other mills find a resale value in bark. Some Oregon producers are selling hammermilled bark for the same purpose, at profitable prices. The Oregon Forest Products Laboratory in Corvallis has undertaken a research program on bark as a mulch.

The back end of the mill received new attention in many regions this year, while the headrig continues the trend of converting to automatic operation. For instance, Richard M. Conner, Connor Lumber and Land, Co., Laona, Wisc. covering the Lake States, reports that three of the four large mills in one area installed riderless carriages in the past year, also several of the small mills. Two mills in the area installed automatic end trimming on their old trimmers and the tendency now is to improve the trimming in the more up to date mills.

In Wisconsin, Goodman Lumber Division, Goodman, Wisc. reported that one of the most important things it was able to do during the past year was install IBM equipment and establish cost centers and cost burdens and apply these to lumber inventories, log inventories and the general ledger.

An important advance in sawmill building was made during the year with the centralized coordination of engineering, equipment and construction

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[1] Contributions by various members of the Division are gratefully acknowledged.

Mayo Lumber Company's highly automated new mill at Nanaimo, B. C. typifies the trend toward the medium sized mill which incorporates modern trends.

to form an efficient producing system. This departure from the traditional sawmill construction method is a particular advantage in highly automated mills where machines function as part of a producing team. Automation sawmills constructed by this method during the year were: Union Carbide Olefins Corp., Sanderson, W. Va., for cutting, 16,000 bd. ft./shift on hardwoods; Mayo Lumber Co., Nanaimo, B.C., cutting 40,000 bd. ft. a shift on Douglas-fir logs; Placerville Lumber Company, Placerville, California, cutting 40,000 a shift on pine; and Cascades Plywood Corporation, Reedsport, Oregon, cutting 60,000 a shift of fir studs.

Regions Try Different Solutions To Solve Their Problems

Professor W. J. O'Neill, University of Missouri, who has reported on the Central Region since the earliest compilation of this Annual Review, states that at Van Buren, Mo. a new gang mill is being installed to cut hardwood and pine and "It may have a big effect on the region—Missouri timber is defective. Gang saw timber may be the answer to better utilization."

In the Appalachian Region, Norman Jackson of West Virginia University notes that the lumber handling facet of manufacturing is receiving more attention at the present time than any other segment. A great many mills are beginning to use steel strapping as a method of packaging lumber along with fork lift trucks to transport the packages in the mill yard. Edge sorters and dipping vats are also gaining impetus in the region.

The same increase in lift truck use and package handling of lumber is noted in Eastern Canada, Northwest Hardwoods and the Lake States. An enterprising small mill operator, Earl Peterson, in Birnamwood, Wisc. has designed a system where his lumber packages will come from the yard to the breakdown where crossings will be removed and the lumber will be freshly double end trimmed at the time of shipment. He feels that this practice will save him degrade and the loss of scale through end checking which occurs when the lumber is trimmed at the sawmill before going into the pile. This practice is successfully followed in the automation mills of Cascades Plywood Corp., Mayo Lumber Company and Placerville Lumber Company.

The stud mill is winning new friends through-out the United States. Developed to a high state of automation in the West the stud mill is erected in a number of eastern locations and is being examined as a solution to problems in several regions.

Overall Mill Sizes Continue Change To Medium Operation

As reported in previous years, there has been a noticeable trend toward shifting from many portable mills to permanently located, larger, more mechanized mills. This trend is particularly strong in the Southeast and Central States. For instance, Union Carbide's new automation sawmill represents the consolidation of the production of several smaller manually operated mills. In the Northeast, also, the trend is from small to medium mills, though current high lumber prices have encouraged small portable mills to open up again. In the Lake States the large mills are gradually giving way to medium sized mills and in Eastern Canada the medium sized mills cutting 30–40 fbm per day seem to be in the ascendency. Some mills in this region are decreasing daily production and changing to a longer season of operation.

A good part of this shift in mill sizes can be attributed to the higher cost of mechanization. The use of debarkers, chippers, mechanized equipment in and outside the mill has become so widespread that mills without this equipment find it difficult, sometimes impossible, to compete. New techniques have been developed for debarking frozen logs and this is increasing debarking in the northern areas.

Forecast For The "Fabulous" Sixties

Forecasters prophesy another banner year for 1960 and, in fact, we are promised that the entire sixties will be "fabulous."

The fifties witnessed remarkable changes in lumber manufacturing techniques. A comparison of the 1951 Annual Review with this 1959 Review shows that many of the "interests" of those years have become standard sawmill practice; that is, riderless carriages, automatic log decks, packaging, debarking, chipping, lift trucks, etc., to name a few.

What are some of the new techniques to look forward to in the sixties? These you can look for: More automation. The application of X-rays or radiation techniques for better log analysis and segregation for automation. Automatic log positioning equipment and programmed sawing cycles. Automatic carriage feeding, automatic edgers, automatic trimmers, automatic tally devices, sorting and inventory control. More packaging: to effectively apply automation, each sawing machine; that is, headrig, edger trimmer, will be considered as a part of a "system" necessitating unified coordination of engineering, equipment construction and installation.

More research: as competition increases and gains from research become more evident in terms of dollars and cents, larger and medium size companies will invest in engineering research programs to solve either specific problems or industry wide problems.

More utilization: as new uses are found for bark, sawdust, chips, wood residues in any shape of form, a higher degree of utilization will be practiced, both in the woods and the mill.

Fig. 1.—A portable crop drier is used to dry corn stored in this pole-type building. Twelve pressure-treated poles support the roof, girts, and snow-fencing in this relatively inexpensive crib.

Fig. 2.—Louvers pressure-treated with a pentachlorophenol-water repellent solution are arranged for installation in wall of test house. Wall section will be raised into position on concrete slab for study of small homes problems. Treated and untreated millwork will receive different priming coats before final paint coat is applied.

PROBLEMS AND PRACTICES IN

Wood Preservation, 1958-9

C. S. WALTERS[1], Past Chairman, FPRS Wood Preservation Division

WOOD PRESERVATION CONCERNS the protection of a broad variety of products, from paper to piling. As a result of this broad scope, many, many problems exist. The problems have great breadth of complexity, and the need for research is omnipresent (9).[2]

One of the problems frequently discussed by representatives of the wood-treating industry concerns the layman's lack of appreciation for preservatively treated wood. In many instances the discussion concerns the home-owner. On the other hand, the chief complaint of the person concerned with acquiring small amounts of treated material is the general lack of a readily available source of supply. In another section of this report, the problem of supply and demand is discussed in connection with the Federal Housing Authority's new requirements for treated house-components (page 74). Two points are apparent: (1) the burden of solving the logistical problem rests with the treating industry, and (2) the promise of financial reward appears to justify the time and trouble needed to solve the dilemma.

Maintaining and developing new markets is a perennial problem. The layman's lack of appreciation of treated wood and his complaint that it is difficult to obtain supplies is another. Solve the logistics problem, and the financial rewards will justify the time and trouble.

Piling: Maintaining existing markets and developing new ones for treated wood are perennial problems for the industry. The strong competition from concrete and steel piling has been partially alleviated by announcements (1, 2, 3) that wood piling test-loaded to 150 tons compared favorably with piling made of other materials. Further efforts to improve wood's place in the piling market were made by the U. S. Forest Products Laboratory and its cooperators. Samples of treated marine piling, judged "good" and "poor" as a result of in-service condition, have been collected. Extractions of preservative oils from the samples are expected to yield information on the amount of preservative required for satisfactory performance under marine exposure.

Crossties: The decrease in crosstie replacements brought about by preservative treatment continues as a result of improvements in railroad traffic control. For example, installation of centralized traffic controls allows one track to carry the same numbers of trains previously carried on double tracking. To date, however, railroads have not found a suitable substitute for a wood crosstie.

Poles: Although the market for building poles appears to be bright as a result of expanded farm (Fig. 1) and industrial use of pole-type buildings (6), some concern has been expressed with regard to the future of utility poles. The Northwestern Bell

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[2] Numbers in parentheses refer to literature cited at the end of the report.

[1] This report could not have been prepared without the help of more than 30 persons who contributed data or made suggestions for improvement. Dr. Ira Hatfield, Wood Treating Chemicals Company, St. Louis, had the responsibility of preparing the first draft of the bibliography. Assistance was given in a highly cooperative spirit, and I acknowledge the help with sincerest thanks.

Telephone Company recently announced plans to spend 1.5 million dollars to bury cables for its western Minnesota–North Dakota telephone routes. The decision was reached as a result of heavy damage sustained by lines during bad snow and sleet storms. The company reported that storm-proofing cables by burying them is a part of a nationwide program of installing trouble-free circuits on important routes.

Reports from utility firms in eastern Colorado reveal that pressure-treated lodgepole pine poles have been deteriorating in 8 to 10 years. Normal service-life expectancy is 30 to 35 years. Inspections showed that improper seasoning caused about 2 percent of the poles to check after treatment and installation. The checks exposed untreated wood and allowed decay organisms to infect the poles. Claims have been made that some of the poles were produced during periods of heavy demand and short supply, and that the consumer too frequently specified clean, dry poles at the expense of adequate retention. The low retentions probably contributed to the poor service.

The Rural Electrification Administration in cooperation with the U. S. Forest Products Laboratory is collecting service records on poles in the REA's lines. The REA expects to release a report on the performance records of over 6,000 poles, probably in 1960.

The technique of analyzing treated wood by extracting the toxicant from sample borings has led to the development of results-type specifications for poles and piling. It appears that similar specifications may be developed for other products, including lumber, laminated products, plywood, crossties, and crossarms. Both private and public agencies are working on the problems.

Particle Board: The increased interest in the manufacture and use of particle boards and hardboards appears to offer a new market to the preservative industry. As service tests (10) of these new board products show the boards to have broad capabilities and uses, the markets for treated boards undoubtedly will expand.

Housing: The Federal Housing Administration minimum property standards for 1- and 2-family living units were modified July 1, 1959, to improve the protection against termites and decay. The use of treated lumber is specified in all areas for sleepers imbedded in, or placed on, concrete slabs, exterior door frames, window sash and frames, access panels, doors and frames in basementless spaces, and for fence posts. Treated wood also may be required by a FHA field office for sills or plates in contact with concrete or masonry within 24 inches of the ground; wood columns in basementless spaces; joists, girders, and similar structural components in contact with concrete and within 24 inches of the ground; furring strips; exterior siding and trim, wood gutters, and other members subject to decay. Pressure treatment is the preferred method of applying preservative, although thermal treatment is acceptable. Brushing, spraying, and dipping methods are not acceptable unless preservative treatment is mandatory.

In the past, small amounts of commercially treated lumber have not been readily available, and its use for residential construction has been limited. Economists estimate that 1,315,000 new homes per year will be started in the next five years. The rate will increase to 1,515,000 units per year during 1965 through 1970. It will be interesting to observe what effect the FHA requirements will have on the availability of commercially treated lumber at the local level.

Cooling Towers: The problem of deterioration of redwood in industrial cooling towers continues to receive consideration. Additional information is being collected on the types of organisms associated with the "soft rot" of fill-slat members, and on the wood-decay organisms associated with typical decay in the interior of the larger structural members of towers. Study of the tolerance of some of the fungi that apparently cause "soft rot" indicates that these organisms may react quite differently to standard preservatives than do the typical wood-decay fungi. Environmental factors such as water, pH, temperature, and nutrient requirements often are quite different from those that affect the common wood-destroying organisms.

Wide use was made of the double-diffusion treatment to control deterioration in towers already in service. Over 200 towers are reported to have received such treatment, many of them being treated within the past year. The evidence indicates that, so far, a double-diffusion treatment with water-soluble salts helps materially to arrest deterioration in the fill material; additional information is needed to determine the full potentialities of the method for extending the service life of the wood in towers. The incorporation of fungicides in the water, with occasional so-called "shock treatments" at high concentrations of toxicants, has been tried, but the value of such treatments is not yet known.

The pressure treatment of wood cooling-tower members prior to erection of the tower has received increased attention. Preservatives containing copper in combination with other materials and coal-tar creosote have been most widely used to date. Service tests in which various species of wood panels have been treated with several standard preservatives and exposed in towers have been initiated. Specifications for preservative treatment of wood to be used in towers are being studied by Committee C–22 of the American Wood-Preservers' Association, but final recommendations have not been prepared as yet.

Millwork: Many studies are under way by government, university, and private research laboratories on the pressure treatment of lumber and millwork (11) with water-repellent—preservative solutions and on the testing of the treated products (Fig. 2). Several problems must be solved before satisfactory specifications can be prepared for such treatment, including the development of methods for conditioning and treating various species of wood to insure paintability, improving the product's resistance to organic deterioration, and providing dimensional stability to the finished product. Simple methods of assaying paintability and water repellency of the treated product are needed. When assay methods are available, then results-type specifications can be prepared for the purchaser's use and the treating plant operators will develop methods that will yield acceptable results.

Boats: Increased interest in water sports and a tremenduous expansion in the use of small boats have increased the number of boat maintenance problems. The failure of wood-framing members or decking as a result of decay has encouraged the owner of wood craft to abandon them in favor of boats of Fiberglas, aluminum, or other material. The treating industry should assume the responsibility for aiding the manufacturers of wood boats, perhaps through the newly organized Wood Boat Foundation, to improve the quality of their products through preservative treatment, thereby maintaining a market for wood that is being lost as a result of lack of treatment.

New uses suggested for treated wood include flights, stop logs, and pipe saddles in sewage disposal plants. Packaged septic tanks, mail-box posts, do–it–yourself swimming pools, clothes-line posts and crossarms, and porch steps, complete with instructions for home assembly of precut, treated

omponents, probably would find a eady market in competition with their ounterparts of nonwood materials.

Although wood treated with fire re-rdants has received only limited re-ognition by insurance rating organiza-ions and the general public, there is tendency to give greater acceptance o such material. Bureaus in most mid-ile-western states and several bureaus n other parts of the United States now ave rating schedules which give a atus of incombustibility to wood eated with fire-retardant chemicals. In some cases the treatment must meet Underwriters' Laboratories standards r have the approval of the insurance ompany. Such a market should be urther cultivated.

Commercial Treatments Decrease

According to statistics compiled by Merrick (14), commercial wood-preserving plants in the United States treated 232.8 million cubic feet of timber products in 1958, the lowest volume treated in 22 years. Production was 15 percent less than that for 1957.

The 1958 estimates were obtained from 352 wood-preserving plants (over 98 percent of the industry), 265 of them with pressure-treating equipment, 63 with nonpressure equipment, and 24 plants who were equipped with both kinds of equipment.

The decline in use of liquid preservatives totaled 41.5 million gallons, a decrease of about 18 percent over last year. The use of creosote declined about 14 million gallons, or 14 percent. With the exception of creosote-pentachlorophenol mixtures, use of creosote mixtures declined—creosote-petroleum about 13 million gallons (26 percent) and creosote-coal tar about 32 million gallons (18 percent). The volume of creosote used in creosote-penta solutions, however, increased from about 300,000 gallons in 1957 to 2.3 million gallons in 1958. The number of plants using the mixture also increased from 4 in 1957 to 16 in 1958.

The use of pentachlorophenol by pressure-treating plants dropped about 300,000 pounds (3 percent) in 1958.

With the exception of two fluorchrome-arsenate-phenol preservatives, water-borne salts were used less in 1958 than they were the previous year. Declines ranged from about 1 percent (Celcure) to 40 percent (Boliden Salts). The use of Tanalith increased about 1 percent (30,000 pounds) and Osmosalts gained about 20 percent (200,000 pounds) in 1957.

The number of fence posts treated increased from 20.8 million in 1957 to 23.2 million in 1958, the only product registering a significant increase in volume treated. Less crossties, lumber, timbers, piling, switches, crossarms, and wood blocks were treated. The number of crossties treated dropped from 31.5 million in 1957 to 22.8 million in 1958, a decrease of about 28 percent and the year's greatest decrease in the use of preservatively treated wood.

About 600,000 fewer poles were treated in 1958, a total production of about 5.4 million. Although the number of poles treated this past year fell below the 1957 total, the use of poles for pole-type structures increased. Approximately 39 percent of the poles produced by 38 of the reporting plants were sold for pole-type structures.

The production of treated plywood rose from 1 million square feet in 1957 to 1.6 million square feet, an increase of about 59 percent.

Approximately 6.3 million board feet of wood products received fire-retardant treatment and an additional 2.6 million board feet received both fire-retardant and preservative treatment. The total volume, 8.9 million board feet, represented an increase of about 13 percent over the volume treated in 1957. The principal products given fire-retardant treatment were lumber (5.7 million board feet) and plywood (921,000 square feet).

The fire-retardant chemicals and the amounts used in 1958 were as follows:

	Pounds
Minalith	1,020,000
Protexol and Pyresote	705,000
Chromated zinc chloride	232,000
Other chemicals	98,000

Application of Wood Preservatives and Fire Retardants

The basic concept of treating wood with toxic chemicals to make it unsuitable as food for fungi has changed but little since it was formed. New methods of imparting decay resistance are being investigated, however. There is some indication that modifying the cellulose in wood by cyanoethetylation, or depleting the thiamin (a necessary minor element for the growth of most fungi) content, will substantially increase wood's resistance to fungi attack. An exploratory study of the chelation of minor elements in wood that are necessary for the development of decay fungi has been initiated by the U. S. Forest Products Laboratory. Preliminary results of these studies indicate that resistance to deterioration may be imparted to wood by destroying or removing from it certain elements that are required by the fungus for growth.

Browne (4) prepared a comprehensive report on the theories of the combustion of wood and its control.

Nonpressure Methods: The practice of treating utility poles at the groundline while in service appears to be an increasing one. Some agencies are giving more attention to methods of treating poles that are being moved from one location to another. In the past there has been some question about the economics of such treatments. New investigations have been initiated to determine the usefulness, limitations, and economies of such treatments.

A group of private companies and public agencies have initiated a cooperative study to compare a number of widely used, commercial groundline treatments. The treatments have been applied to pole stubs as well as poles in line. Several commonly used species of poles are included in the tests.

The U. S. Forest Products Laboratory is testing soaking treatments for exterior building components such as porches, steps, and columns, in cooperation with the U. S. Navy, Bureau of Yards and Docks. The investigation has two major objectives: (1) to ascertain the effectiveness of short-soak treatments of new wood after it is cut to final size and before the part is put in the structure, and (2) to determine the effectiveness of treating the completed structure by flooding joints and other water-collecting areas with preservative solution, using hand-operated equipment to apply the solution.

Test Methods for Preservatives

The American Society for Testing Materials (ASTM) voted to continue Tentative Method 1413–56T, "Testing Wood Preservatives by Laboratory Soil-Block Cultures," in a tentative status for another year.

ASTM Subcommittee 13 of Committee D7 prepared the first draft of a new method for standardizing the field testing of preservatives by means of ¾-inch stakes. The new method for accelerated testing of wood preservatives is expected to be submitted for ASTM approval as a tentative standard late in 1959.

The U. S. Forest Products Laboratory continued its efforts to simplify and to improve the soil-block method for testing wood preservatives (5, 8). McKnight found (12) that the logistic function was a more descriptive means of measuring the action of a fungicide over a range of toxicant concentration than the threshold value commonly used.

The assay of preservative retention by extracting borings with toluene, proposed by Baechler at the 1958 convention of the American Wood-Preserv-

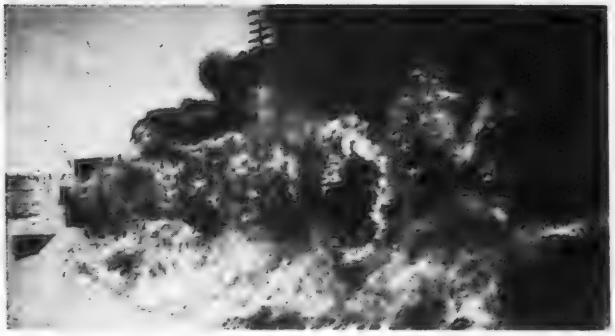

Fig. 3.—Full-scale trestle replica in fire test 45 seconds after ignition. Douglas-fir timbers were treated to refusal with 0.9 percent phosphorus as triarylphosphate in a creosote-petroleum mixture.

Fig. 3a.—Little damage has been sustained by this full-scale, trestle replica 8 minutes after structure was ignited in burning test. Some local burning still persists in protected pockets.

ers' Association, appears to have met the approval of the commercial treating industry and some consumers of treated wood. It seems likely that in the future acceptance or rejection of treated products will be based upon a quantitative assay of extractions obtained from borings rather than on gauge readings or weight measurements. Assaying distribution of the preservative in the treated product will need to be made by observation of borings until a more analytical method is developed.

A report on the possibilities of coupling pentachlorophenol with an aromatic amine to form a colored compound in treated wood was made by Walters and Meek (16). They concluded, however, that their results were not distinctly better than other methods currently used to assay preservative penetration.

New Preservative Chemicals

The Osmose Wood Preserving Company, Buffalo, New York, announced the formulation of "Osmose PFR," an inorganic salt mixture that provides fire-retardant properties as well as decay resistance to wood treated with the chemical.

The results of testing tributyltin oxide as a preservative for plywood and for poles in service (applied by spraying) has been encouraging. Additional tests are planned by private and public agencies.

Investigators at the Ottawa Laboratory, Forest Products Laboratories of Canada, reported (13) copper abietate gave good protection against copper-tolerant *Poria monticola* and that it was resistant to leaching. Copper formate, fixed in the wood by a steam treatment, was resistant to leaching, but it gave poor protection against *P. monticola.*

Although creosote and pentachlorophenol have been in use for a number of years and are not new preservatives, using a mixture of the two preservatives is a rather recent development. Fortified creosote, containing 2 percent (by weight) pentachlorophenol, promises to give a synergistic effect that will make the mixture more valuable for some uses than either of the two components. However, certain probelms have arisen from the blending of the two preservatives, such as an increase in the amount of benzene-insoluble materials.

Regional Activities

North Central Region: The Central States Forest Experiment Station and the Ohio State University Research Foundation are cooperatively investigating methods and equipment for locating defects in standing trees, logs, and timbers with radioactive materials. The principle of attenuation of gamma rays has shown considerable promise in laboratory tests (15). A portable scintillation spectrometer is being built and field-testing of the new technique probably will start in 1959.

The Rural Electrification Administration sponsored a "pole clinic" in cooperation with the University of Wisconsin, June, 1959. Over 90 persons representing REA cooperatives, public utilities other than REA, private utilities, universities, commercial treating companies, and chemical supply houses attended the meeting. As a result of the clinic's success, it is expected that similar functions will be held at other universities in various parts of the country.

The University of Minnesota School of Forestry reports the testing of a wide variety of treated materials for pole-type structures. Approximately 25 experimental buildings at the Rosemount Research Center have been built with treated and untreated components and finished with a variety of paints and pigmented wood preservatives.

South Central: The Department of Forestry, Alabama Polytechnic Institute, served as host for the 12th annual meeting of the Coordinated Wood Preservation Council. Inspection reports were made on aboveground testing of oak and pine newel post-stair rail assemblies. Test specimens were treated by brush, 2-minute dip, and 15-minute dip methods with pentachlorophenol solutions containing water repellents.

The Council voted to continue cooperative research on the use of on-the-job preservative treatments for wood installations not in contact with soil. Cooperating agencies expect to install a series of test assemblies that have been treated with copper naphthenate solutions containing 1 percent copper metal.

The 13th annual meeting of the Council was held November, 1959, at the University of Florida.

A method that would shorten the air-seasoning period for crossties would materially benefit the commercial treaters who stock large tie inventories in order to maintain production schedules.

The Langlade Company, Valdosta, Georgia, reports oak crossties were successfully seasoned by shed-drying for six months as compared to 12 months normally required to air-season oak ties in an open yard.

The University of Florida's School of Forestry has found that sweet gum crossties can be seasoned to a moisture content level suitable for preservative treatment by forced air-drying (FAD) for approximately 45 days. Florida investigators expect to season oak ties in

Fig. 4.—Southern pine posts are burned in a test of fire-retardant eatment. Some posts were cold-soaked either in a pentachlorophenol –fuel-oil solution or in a solution of pentachlorophenol containing n oil-soluble phosphate derivative. Untreated posts serve as controls. he test plot will be burned annually and posts stressed as cantilever eams to measure effect of burning.

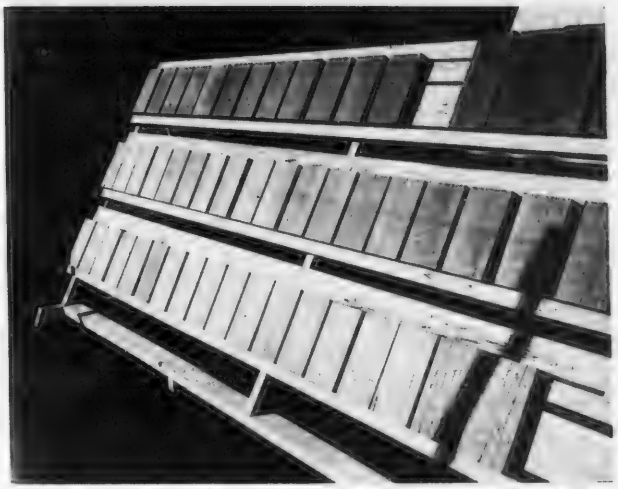

Fig. 5.—Treated and untreated wood blocks approximately 2" x 6" x 12" are exposed on a weathering rack in a study of the effect of exposure on dimensional stability.

100 days. No heat or buildings were used. The fan unit and tie-stack roofs were moved to position with lift trucks.

South and Southeast: The pressure treatment of lumber, posts, poles, and ties with oil-type preservative apparently has changed little in the past year. There appears to be some increase, however, in the amount of lumber treated with water-borne salts for use in house construction.

The double-diffusion method is being used commercially by at least three small plants to treat fence posts and lumber. Everdure, Inc., Orange, Virginia, offers post-and-rail fences, lawn screens, posts, stakes, gates, cattle guards, and lumber treated by soaking the wood in an aqueous solution of copper sulphate followed by a second soaking period in disodium arsenate. Copper arsenate, a compound toxic to fungi and insects and highly resistant to leaching, is precipitated in the wood.

Because hickory is being more widely accepted for crossties in the Southeast, the Hickory Task Force is preparing a report on the preservative teratment of this species.

Rocky Mountain and Inland Empire: The Intermountain Forest and Range Experiment Station reports that treatment and sales of lodgepole pine posts have expanded as a result of highway relocation projects and the construction of highways under the federal highway program. The general outlook for the treaters in this area appears to be good.

The testing and use of oil-soluble, organic phosphate compounds as fire retardants (Figs. 3 and 4) increased during the year. Because the fire-retardant chemicals can be mixed with creosote, western railroads are now specifying such treatment for bridge and trestle components.

The groundline treatment of poles was given considerable attention in the Central Rocky Mountain region during 1958–59. The major problems appear to concern the improvement of a procedure for determining the condition of poles in service and the evaluation of the effectiveness of various groundline treating methods.

During the past year Colorado State University forest products specialists initiated a study of sampling techniques for evaluating the condition of poles in service. The major objective of the investigation, made in cooperation with REA cooperatives and groundline treating agencies, was to develop a standard inspection technique. The study revealed that the replacement needs for poles were about normal for the area. Improper seasoning appeared to be an important contributor where premature failure of poles was detected. Seasoning checks appeared to be the cause of most of the difficulty.[3] The study also revealed that groundline conditions, even in the semi-arid areas, frequently had the factors necessary for decay and that the decay hazard should not be disregarded when treating requirements are under consideration.

Another basic problem in the area is the need for an effective method for treating Engelmann spruce. The species has good form and a good supply of pole-sized trees is available in the Rocky Mountain-Inland Empire area.

There was a marked increase in interest in ponderosa pine poles during the past year. Demands for future sawtimber crop trees conflict with pole production so that the supply of pole-quality stems becomes a special problem with the species.

Pacific Coast: The Oregon Forest Research Center reports their investigation of the treatability of Douglas fir shows that longitudinal permeability varied with geographical location. Specimens obtained east of the Cascade Mountains were highly refractory. Specimens obtained along the Cascade Range were semipermeable, with penetration largely in the summerwood. The most easily penetrated wood was obtained from trees growing west of the Cascades. Penetration across the grain was poor in all specimens. The investigations are being continued to find out why the heartwood varied in permeability.[4]

The Center also initiated work on methods for preventing or controlling checking of round wood members, primarily to reduce checking of poles and piling after treatment, and on the preservative treatment of Douglas-fir plywood.

Reports on a new type of pole incisor built by the Cascade Pole Company, Olympia, Washington, indicate that the machine is working successfully in improving pole treatment and may help reduce deep surface checks in Douglas-fir poles. The machine consists of 20 small, air-operated rolls fitted with standard Greenlee teeth and mounted around an opening in a metal plate. The pole is fed through the opening, tip first, and the incising rolls retreat as pole diameter increases. The incisions are about ¾ inch deep.

Investigations of the Los Angeles Harbor Department (LAHD) concerning wood in marine environments

[3] Note reference (see "Pacific Coast") to investigation initiated by Oregon Forest Products Research Center on methods for controlling checking in round products and to use of pole incisor by Cascade Pole Company.

[4] See 2nd paragraph, "Western Canada," page 78, and the reference to quick test for determining treatability of Douglas fir developed by the Vancouver Laboratory, Forest Products Laboratories of Canada.

have centered around field-testing various kinds of barrier coatings for repairing wood piles under attack by marine borers, while the poles are in service. Because of the relatively short service life of creosoted wood piling (reported as less than 15 years), the LAHD has preferred to use concrete for marine piles. If a satisfactory barrier coating can be developed for wood piles, the department believes that annual maintenance costs will be reduced hundreds of thousands of dollars. Field tests of several types of materials were initiated during the year, with applications successfully made to under-water portions of wood piling by a diver.

The California Forest Products Laboratory is continuing its study of the bacterial attack of pine logs in pond storage. Investigators who are attempting to identify the bacteria responsible for the attack, are particularly interested in those organisms which apparently give pine sapwood increased permeability to preservative liquids.

Eastern Canada: Reports have been received on the expanded use of crossties treated with pentachlorophenol in heavy petroleum oils by Canadian railways. The reports did not state whether the expanded use constituted pilot plant testing of the preservative or complete acceptance of the treatment.

The Ottawa Laboratory, Forest Products Laboratories of Canada, is investigating the electrical conductance properties of preservatively treated poles. Samples of red pine sapwood treated with creosote, pentachlorophenol in petroleum oil, greensalt K, or Boliden Salt S–25, and untreated controls were tested at different moisture contents. Samples of sapwood obtained from fresh-water driven, salt-water driven, and nondriven western red cedar poles also were measured for electrical conductance. Two methods of measuring conductance have been used: the 4-pin method developed by the Bell Telephone Laboratories, Inc., and the use of silver micro-paint, a technique developed at Ottawa. Other variables which were either controlled or varied are: the effect of temperature, the voltage gradient, and the effect of knots.

The Ottawa Laboratory also is studying the losses of pentachlorophenol from pressure-treated wood poles in cooperation with a telephone utility. Samples of wood were removed from one pole of a group that had been in service and that had exhibited closely observed preservative losses over a number of years. The amount of preservative left was determined by analysis, and the measure of protection against decay was evaluated by soil-block tests with *Lenzites trabea*. Further consideration is being given to the effect of the losses of penta in an effort to determine expected pole life more exactly.

A large number of veneer and plywood specimens were treated with a well-known fire-retardant solution to include a range of retentions and several species of wood. A large producer of hardwood plywood, who is cooperating with the Ottawa Laboratory on the study, is now making gluing tests with the treated veneer and plywood.

An in-service test of 1,000 crossties of 10 different species pressure-treated with zinc-meta-arsenite and installed by the Ottawa Laboratory in 1930, was concluded during the past year. Average life was 22.2 years, far short of the service obtained with oil-type preservatives. Many of the ties removed did not appear to be decayed but were checked, split, or shattered.

Investigations continued on the nonpressure treatment of green fence posts by sap displacement, a method especially suitable for farmers. Bolit, a form of Boliden Salt especially formulated for this method of treatment, is being used. Treatments were considered satisfactory by Ottawa Laboratory investigators. The effect of partial seasoning on absorption and penetration also was observed.

The first Osmose pressure-treating plant in Canada was installed in central Ontario, and a second pressure-treating plant to use Boliden Salt was installed in Manitoba.

Western Canada: The Vancouver Laboratory of the Forest Products Laboratories of Canada is preparing a report on its investigation of the factors which influence the injection of preservative into western hemlock poles. Experiments in conditioning wood by Boultonizing and by steaming and use of vacuum, as well as by other methods, were designed to learn the effects of pressure, temperature, and moisture content on treatment.

Due to the fact Douglas fir obtained from different sites treats differently, Vancouver investigators developed a quick test that may enable operators to segregate refractory wood from wood which can be treated with relatively little difficulty before the material is placed in the retort.

Puerto Rico: The U. S. Forest Service's Tropical Forest Research Center reports much progress has been made in the field of wood preservation during the past year. Because of the high decay and termite hazards and the fact that many Puerto Rican species are not naturally resistant to organic deterioration, adequate preservative treatment is an important consideration in the utilization of wood in this tropical area.

A 6- by 40-foot pressure cylinder installed in 1957 is operating at full capacity treating southern pine lumber, mostly with Wolman salts. The treated pine is used in local construction of commercial wood buildings.

The Commonwealth of Puerto Rico recently installed an experimental treating plant with a 3- by 10-foot cylinder. The plant has the same design as one recently installed in East Pakistan under an International Cooperation Administration—U. S. Forest Service contract. It will be used to determine the treatability of local species that may be used for fence posts and lumber. Both pentachlorophenol and creosote will be included in the tests.

The Tropical Forest Research Center at Rio Pierdas recently completed treatability tests on 53 species suitable for fence posts, using pentachlorophenol applied by cold-soaking; 22 species were treated with pentachlorophenol by thermal treatment (hot-cold bath). In addition 10 of the species were treated with a 50–50 solution of creosote and diesel oil by cold-soaking and by thermal treatment. The treated posts have been set in test plots for periodic inspection. Results of the treating investigation are being prepared for publication in the near future.

A treatment of 23 species by the double-diffusion method has been initiated, using a 5-day soak in sodium fluoride solution followed by a 3-day soak in copper sulfate solution. Plans for the investigation also call for testing a second combination of chemicals consisting of a 2-day soak in copper sulfate solution followed by a 2-day soak in a 50–50 sodium arsenate-sodium chromate solution.

Hawaii: Reports from Hawaii indicate the major problem in the use of wood is protecting it from attack by termites, although decay also is a problem. It is estimated by the technical staff of the Honolulu Wood Treating Company, Ltd., that 75 percent of the termite damage is caused by subterranean species and 25 percent by dry-wood termites.

Entomologists indicate that the dry-wood termite is found in practically every frame building on the Island of Oahu. Infestations in Honolulu buildings are much greater than those in buildings located in the outskirts. Building inspectors for the city and county of Honolulu report heavy termite damage to buildings in many districts, with repairs estimated to run from 20 to 50 percent of the permit values. Damage estimates are difficult

make because of the hazards involved in appraising termite damage and because many repairs are made by building owners who do not obtain construction permits. However, the total estimated expenditures spent in 1956 for repairing buildings damaged by termites in the city and county of Honolulu was $3 million.

Furniture, millwork, and other wood products may be attacked by termites while in storage as well as after the products are installed for use (7).

Alaska: Koppers Company, Inc., will build and operate the first wood-preserving plant in the 49th state at Whittier. The plant will be built on property leased from the Alaska Railroad and adjacent to the Columbia Lumber Company. The plant is expected to be in operation by July, 1960.

Only one treating cylinder is being installed at present, but it will be able to pressure-treat with creosote, Wolman salts, or with fire-retardant chemicals. Although termites are not a problem in Alaska, decay and marine borers attack wood. In many Alaskan areas fire-protection equipment is operated with great difficulty during subzero weather. Wood treated with fire-retardant chemicals is expected to find a ready market in these areas.

The preservative chemicals will be shipped to Whittier from Seattle, Washington; steam and electricity will be supplied by the Columbia Lumber Company; timber is available from the Chugach National Forest. Western hemlock is expected to be used predominantly.

Association Activities

The National Woodwork Manufacturers Association has recognized the importance of treating millwork with toxic solutions that do not discolor or swell wood and that dimensionally stabilize the finished product. One of the major problems confronting the woodwork industry is the difficulties experienced in painting wood treated with oil-borne preservatives containing water repellents. The results of early investigations by public and private laboratories are conflicting. The NWMA is continuing to support research at the U. S. Forest Products Laboratory that is designed to correlate laboratory tests for water repellency with performance of millwork exposed under service conditions (Fig. 1).

The NWMA program is guided by its Preservatives Standards Advisory Committee, a group of approximately 30 specialists in the field of wood preservation. The Committee voted this year to substitute the soil-block method (ASTM Standard D1413–56T) for the NWMA's present method of evaluating wood preservatives. The recommendation, however, must be approved by the NWMA membership before becoming final.

A meeting of the National Association of Corrosion Engineers' Committee T–9 was held in June, 1959, at the Seahorse Institute. Several reports were given on the use of living organisms to screen wood preservatives for marine installations. Controlled tests in which wood samples were exposed under laboratory conditions to *Teredo* or *Limnoria* were discussed.

The Western Wood Preserving Operators Association successfully initiated an educational program to promote the use of treated wood in highways and to build good will for the industry.

The Cooling Tower Institute approved standards for pressure preservative treatment of lumber. The standards are based on extensive studies made by the Institute and reported in "Wood Maintenance of Cooling Towers." The Institute moved to new headquarters at 1120 West 43rd Street, Houston 18, Texas.

The Rocky Mountain Pole and Treating Association elected D. R. Meigs, B. J. Carney and Company, Spokane, Washington, president, and A. D. Decker, secretary. The RMPTA, in cooperation with the U. S. Forest Service, is studying pole production trends in the Northern Rocky Mountain Region.

The American Wood-Preservers' Association revised 10 standards and added three new standards to its Manual of Recommended Practice. The revisions and new standards incorporated recommendations that were made by the Association's technical committees and confirmed by a vote of the membership.

New standards included specifications for the pressure treatment of wood used on farms, the fire-retardant treatment of plywood, and for determining water and oil-type preservatives in wood.

The American Institute of Timber Construction reports that a standard specification for gluing treated wood and for the treatment of glued wood has been developed.

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Status of Wood Drying -- 1959

J. M. McMillen, S. B. Preston, and C. J. Kozlik
Report Subcommittee, FPRS Wood Drying Division

Significant industrial progress on preseasoning treatments, air drying, kiln drying, special drying methods, shipment and storage, applied and fundamental research, and specifications are discussed.

THE TECHNOLOGY OF WOOD DRYING has continued to improve to meet the ever-increasing demand for high-quality wood, properly seasoned, for high-quality products. This report attempts to show where wood drying technology and practice stand today by a compilation of reports on commercial practice from various parts of the United States and Canada and by a separate report on European developments by W. H. Brown.[1] To indicate what the future developments will be, a brief discussion of published applied and fundamental research, along with a number of references, is given. Research still in progress or developments not yet at commercial stage are not reported. This review covers significant industrial events since 1956,[2] and the more significant references since early 1958.

In the last bibliography on wood drying,[3] a number of Russian publications were cited. This current review lists just one. Russian Science, however, has continued active in the seasoning field. Titles of Russian papers may be found in the *Bibliography of Agriculture*, U.S.D.A. Library, and the *Russian Accessions*, Library of Congress. Some translations are available.

Preseasoning Treatments

A major development in preseasoning treatments was the prevention and control of brown stain during drying of green sawn sugar pine and Idaho white pine. Control, accomplished by dipping in sodium azide, was developed by the Western Pine Association (52).[4] The treatment has enabled western pine mills to lower costs in terms of shortened kiln schedules as well as improve quality by stain prevention. The method does not appear applicable to ponderosa pine, but may be effective with eastern white pine.

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The well-established practice of toxic dipping both pine and hardwoods of the South and various softwoods on the West Coast to control fungus blue stain is continuing and spreading into other areas where stain losses are less frequent but costly when they occur. A new comprehensive report (79) covers green lumber, as well as log, treatment.

Individual redwood mills, along with the Redwood Seasoning Committee of the California Redwood Association, have conducted extensive tests to determine effectiveness, economics, and coverage of end sealers for redwood to be air seasoned. Favorable test results have led to extensive commercial use of the wax-emulsion type end coating in large quantities. Use of heavier-type end coatings to prevent end checking and honeycombing in refractory items continues where needed.

A number of southern, central, and eastern firms have used Lumber Cure, a buffered sodium chloride, or ordinary salt on thick material, particularly oak, hickory, and beech, to reduce surface checking during air drying. The chemical enables southern firms, particularly, to extend the period when they can cut such material. Wider use has resulted in an increased number of reports of serious damage resulting from excessive application of chemical or use of the lumber in an unsuitable application. These reports involve an incompatible glue or finish or sweating and corrosion on a product to be used in a humid location. The treated lumber also is unsuited for electronic gluing. Because of these difficulties, there is a general feeling among users that producing firms employing Lumber Cure or salt should plainly identify the treated lumber.

Western mills are sprinkling log decks to control stain and log checking and using green storage sheds, individual roofs, or sprinkler sytsems to protect green lumber prior to kiln drying. These practices are being used to a lesser degree in other parts of the country.

Air Drying

Throughout the United States, the trend toward unit package piling, with better stacking, roofing of piles, and revamping of yards, has gained considerable momentum. Many of the more efficient mills, large, medium, and small, build package piles exclusively. In the Northeast and Central regions, package handling is finding acceptance in smaller operations with mills producing as little as 8 to 10

Fig. 1.—Wide spacing, high, open foundations, and tight pile roofs are common practice in air-drying redwood.

[1] W. H. Brown, Timber Specialist, Remploy Limited, London.

[2] L. D. Espenas, "Status of Wood Drying in 1956," For. Prod. J. 7(2):67-71.

[3] S. B. Preston and D. E. Nelson, "Wood Seasoning Bibliography, 1956-7," For. Prod. J. 8(2):81-84.

[4] Numbers in parentheses refer at the end of this report Literature Cited.

Fig. 2.—Forced-air lumber drier adaptable to single-pass or heated-air recirculation. (Photo courtesy Moore Dry Kiln Co.)

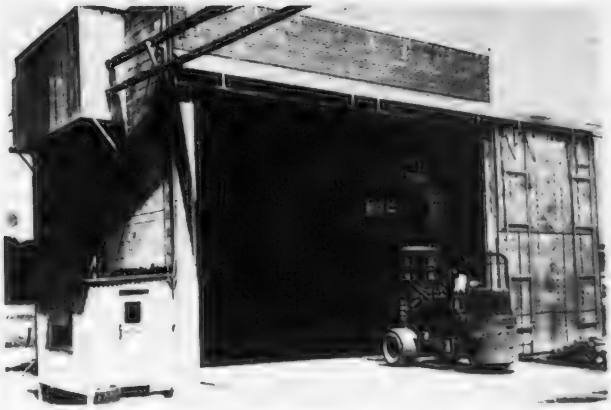

Fig. 3.—Package-loaded, steam-heated, reversible internal-fan kiln.

M b.m. daily using forklifts and automatic stacking equipment. Some secondary manufacturers using as little as 3 to 5 M b.m. daily have converted to package handling. In a study comparing various stacking methods in Georgia, package-pile southern pine lumber showed up best in uniformity of drying, rate of drying, and reduced seasoning degrade. In Canada, especially in Alberta and interior British Columbia, unit packaging is being used more frequently, but there is still room for improvement in the practices. There has also been some expansion of the use of wide spacing between air drying piles (9), first shown to increase the output of dried lumber per unit area of yard by the Redwood Seasoning Committee.

More seasoning yards in the South are grading and surfacing better, with favorable drying rate results. One firm, after experimentally black-topping a portion of their yard, plans to blacktop the entire yard. The surfacing eliminated wide moisture content variation from top to bottom of the piles, a variation that had seriously affected kiln drying schedules and final moisture content results as well as yard throughput. The blacktop stored enough heat during the day to increase the drying of the lower lumber courses at night. This practice is expected to spread throughout the South.

In addition to the general trend for package handling, there is another trend in the Northeast toward palletizing rough furniture dimension stock. Incoming stock is end coated and strapped on pallets for storage in the yard and handling into and out of the kilns.

Several research studies have shown that roofing hardwood piles results in cash savings. Stack covers have become more common commercially, and several firms in the Southeast have roofed all or part of their seasoning yards. Using pole-type construction, such sheds can be built for 50 to 95 cents per square foot in the Southeast and $1.25 to $1.50 in the North. Such sheds can be designed in a manner to reduce fire hazards (5). Advantages of roofing the entire yard are faster and more uniform drying, reduction of surface checking, and reduction of warping of top layers in the piles.

Accelerated Air Drying

The use of low-temperature forced-air circulation, either with or without a low-cost building, to accelerate the drying of wood customarily air dried or shipped green has expanded considerably. In the preparation of hardwoods or redwood for kiln drying, it is called predrying. It is also used to reduce shipping weights of softwoods or to dry them low enough in moisture content for some construction uses without further kiln drying. Several major kiln or drying equipment firms have entered this field.

A number of southern industrial users, pleased with their results, have reported (8, 36) quicker turnover, lower inventories, reduced yard space and handling costs, control of chemical stain and sticker marking and reduced warping and checking with medium density and soft hardwoods. Some harder hardwoods present hazards of checking and honeycombing, however, and require control of drying conditions. A northern lumber firm reported less spectacular, but still satisfactory, results during favorable weather. One southern user supplies enough heat to maintain a relative humidity of 75 percent or less during night hours when drying magnolia and bay, and completely eliminates chemical blue stain. Several new northern installations are providing for slight heating during winter months. In the West, softwood producers have used temperatures of about 110° F. on redwood and 113° F. on ponderosa pine without strict equilibrium moisture content control.

In contrast to satisfactory statements of producers and self-users, some manufacturers purchasing predried hardwoods have reported moisture content higher and less uniform than customary in air-dried stock. A southern custom drier, however, reports a preference for fan-dried soft hardwoods over stock air dried by mediocre practices.

Both successful and unsuccessful commercial use of forced-air drying goes back many years. The process operates on the basic principles that a large part of the free water can be removed from green wood as fast as it evaporates from the surface and that surface evaporation is greatly dependent upon air circulation rate and turbulence. Fundamentals often ignored in poorly designed driers are that evaporation cools the air, and long air travel through the load causes cooling to the dewpoint, with consequent saturation and cessation of evaporation.

The time now appears to be here for widespread use of low-temperature forced-air drying as a tool, along with good air drying and kiln drying, to do the high-quality lumber drying job industry needs. Commercial application is going ahead very rapidly without sufficient technological information. Two types of information are needed: (1) information on best combinations of equipment and procedures and (2) cost data, in comparison with good air or kiln drying. A few technological reports, however, are included in the references (30, 74).

Kiln Drying

The demand for kiln-dried lumber is increasing, including lower grade material and heavier members. More companies are erecting new kilns, replacing old ones, or enlarging capacity. This is especially true in the North Central, Rocky Mountain, and Southern regions. Practically all of the new kilns installed in the West and North have been the steam-heated, reversible internal-fan, cross-circulation compartment type. In the South, this type is also heavily favored, but the drive to-

ward kiln drying has resulted in heavier sales of gas-fired kilns also. Steam-heated kilns are still in the majority in Canadian operations, but the arrival of natural gas at low rates on the Coast has created considerable interest in direct-fired kilns. Several are presently in operation. The kiln manufacturers have turned more toward noncorrosive materials, including cast aluminum, heat-resistant plastics, and asbestos-cement board. There have been improvements in equipment such as doors and vents. The design of practical prefabricated dry kiln buildings and the availability of "packaged" automatic gas- and oil-fired boilers, as well as prewired electrical and control panels, have been significant. There also have been some sales of kilns that do not conform to the widely accepted features of modern dry kiln design. As an aid to its membership, one of the major wood-producing associations has set up specifications for minimum requirements for new dry kilns (53). In the North, the trend toward package handling of lumber has resulted in a large proportion of the new kiln installations, perhaps more than three-fourths being of the package type. An international catalog on dry kilns has been issued by FAO (28).

Mechanical stacking has long been part of efficient kiln drying operations in the West, a region which has the lowest overall cost of kiln drying. This practice is growing fast in the eastern parts of the country also. Added now to this is expansion of mechanical aids to sorting. These two, plus mechanized yard and mill transportation, are doing much to move handling and drying of lumber along toward complete mechanization, with lower costs and improved quality. While this overall development would seem to favor larger concerns, equipment is also available and is proving economical for medium and smaller firms.

A new development of modern industry that should aid high-quality kiln drying, dependent on automatic 24-hour operation, is the use of a commercially separate monitoring system. Such a system has been installed at one plant in the Southeast. The American Dispatch Telegraph Company installed the monitoring devices within the plant, in addition to the more customary fire and burglar alarms. At a remote location, the answering service notifies the kiln operator in case of misfunction. Basically, a duplicate set of instruments is used in the kiln control room. Relays operate if the desired span or tolerance is exceeded. By use of a time-delay device to take care of variations at fan reversal, these tolerances can be set at $\pm$ 2° F.

In the field of kiln operation, suggested kiln schedules for thick hardwoods have been published (64), also a revised edition of the British publication (33) giving schedules for many foreign woods. A book giving many practical suggestions for commercial kiln operation has been published by Devine (22). In the Northeast, a number of dry kiln operators have been using part-time drying with the heat off at least half of the time in the kiln. They reported little increase in drying time, equal quality with full-time drying, and considerable savings in drying cost. In the West, companies and kiln operators are becoming more aware of proper maintenance of kilns and equipment and of the factors that promote good drying. Drying schedules are constantly being reviewed and revised to meet the consumer demands. A number of dry kilns of the Northeast are equipped with a multi-station electric moisture measurement system to follow the moisture content of the wood and determine when to change drying conditions. Satisfactory results have been reported after compensating settings have been developed for the various woods and drying conditions involved.

Kiln drying is the only present way to produce lumber at a low average moisture content with a high degree of moisture uniformity and with stress and set relieved, and while this is done at a comparatively low cost, management is justifiably concerned with this cost (81). Degrade is a factor. While kiln drying has generally held degrade to low values, incompletely controlled factors result in more than is necessary. A few studies (1) have been made of degrade occurring at various mills under the present seasoning procedures. Studies to find the effect on degrade of varying the procedures are needed.

During the last few years, a number of custom kiln drying firms have come to maturity. Their business, largely located in the eastern half of the United States, is mainly concerned with hradwoods. Most of the material is air dried or predried before kiln drying, but some green material is also custom dried. Such firms make great use of package-loaded kilns and a variety of kiln-drying equipment.

There is some trend in the field of drying wood treated with water-borne preservatives or fire retardants for better and more complete seasoning. One major eastern firm reports that about 2/3 of its output of fire-retardant-treated wood and about 1/3 of preservative-treated wood is kiln dried. An additional 5 percent of the latter is air dried.

High-Temperature Kiln Drying

Summaries of Canadian work in high-temperature drying have been published (18, 34). These discussed certain practical aspects, including incidence of seasoning defects, energy consumed, and the stability and general working properties of wood subjected to the process. Another publication of the Ottawa Laboratory (58), presenting suggested high-temperature drying schedules for a number of eastern Canada softwoods, may be considered a manual on this subject. Widespread commercial application of the method has not followed the research. In North Carolina, a kitchen furniture manufacturer has been carrying out high-temperature drying on soft hardwoods using temperatures up to 230° F. No data have been published on the schedules or equipment.

Special Drying Methods

The vapor-drying process, employing hydrophobic xylene vapor or the like to reduce the moisture content of green material sufficiently to permit preservative treatment, continues to expand. A new plant in Texas, involving a $2 million investment, is currently drying 40,000 hardwood crossties per month. The process has also been applied commercially to previously air-dried cativo lumber. Excellent results in removing exudable resins and residual moisture are reported without drying degrade. Average retort time is 12 to 14 hours for 4/4 stock. Solvent retention is generally below 2 percent. This application may be suitable for other woods with considerable resin.

Industrial research continues with a number of boiling-in-oily-liquid methods. Many species of "easy-to-dry" wood can be gotten very dry in a few hours by this process. Excessive stress development, drying defects in refractory woods, solvent absorption, and increased inflammability in some cases, as well as difficulty in arriving at a uniform final moisture content suitable for ultimate use, have limited the method. Current developments have not reached the commercial stage. Experimental work has also continued with solvent seasoning using acetone, a hydrophilic liquid that keeps the wood in a swollen condition during water removal. An extensive bibliography on special seasoning methods has been assembled (55).

Drying Non-Lumber Materials

Information on drying wood particles and veneer has been included in this review to help maintain a broad

approach in the drying of all types of wood materials. During the 1957 Madison Conference, a principle brought out on the drying of materials other than wood was the desirability of reducing the material to the smallest-sized particles permitted by the final use before attempting the drying operation, then using very severe drying conditions. This principle is used advantageously in the drying of veneer and wood particles.

The bulk of veneer, both softwood and hardwood, is dried in steam-heated mechanical driers. Hardwood driers generally are operated in the temperature range of 230° F. to 300° F. Most softwood driers operate between 300° to 400° F. Roller-conveyor driers are most commonly used for rotary-cut veneer. Wire mesh conveyors are frequently used for sliced veneer, helping to maintain consecutive veneer sequence. Direct-fired oil and gas driers operating at 500° to 550° F. were introduced on the West Coast several years ago, but veneer dried at these temperatures was found unsuitable for exterior-type plywood. Today they are used for interior plywood veneer. In a few cases they are operated at lower temperatures and used as boosters for steam driers. Infrared drying was found to have no economic advantage over steam driers. Only a very small volume of veneer is being dried in dry kilns at temperatures under 220° F.

Wood particles (flakes, shavings, sawdust, etc.) used in the manufacture of particle boards and dry-formed hardboards are presently being dried by a variety of means (77). The choice of equipment is usually dictated by the type of particle and the quantity to be dried. Types of equipment in common use are: (1) rotary-drum driers, (2) belt or conveyor driers, (3) hot air suspension driers, and (4) direct-fired suspension driers. The air temperatures used in the first three methods are those normally associated with high-pressure steam heat exchangers or 300° to 350° F. In the direct-fired suspension type drier, the particles are dried in a mixture of air and the products of combustion (from burning oil or gas) and the temperatures of this mixture at the time the particles are introduced are normally in the range of 500° to 1,500° F.

In the seasoning of material larger than lumber, a new report of the Hickory Task Force (91) summarizes recent research and industry practices in seasoning hickory crossties. Air drying, controlled-air drying, kiln drying, and vapor drying are covered. By solving seasoning and other problems, research and industrial development have permitted the annual utilization of hickory crossties to increase by a million since 1952. A symposium on seasoning and conditioning for preservative treatment was held by the American Wood Preservers Association in 1958 (13).

Dry Lumber Shipment and Storage

More attention is needed to dry lumber shipment and storage. In both producing and consuming areas, however, the use of coverings or wrappings has afforded excellent protection for lumber during storage (38). The added cost has been easily offset by the benefit gained in keeping the lumber dry and protected from the weather. Heated shed storage, however, is preferred for kiln-dried hardwoods (29).

The railroad car with its small door is a bottleneck in maintaining high handling costs and causing unproductive work for lumber producer, custom kiln drier, and ultimate lumber user. Although a large number of western mills are equipped to bundle lumber in wrappers before shipment, bundling for flatcar shipment does not seem to be the answer. It has proven expensive to stake and strap the cars. Development of the wide-door car, with forklift truck loading, has gone beyond the experimental stage, but expected production of new cars is necessarily low. Another development is boom-type loaders for the existing cars.

In the North there is a strong trend to truck shipment of dry lumber, both long and short haul. This ties in with forklift truck loading and unloading, and the trend toward exclusively package-loaded storage in newly established facilities. Tarpaulins are used to keep the lumber dry enroute, but failure to cover all sides adequately allows rewetting during rains or wet snowstorms.

Paper wrapping of small quantities of the higher grades of lumber has been favorable for consumer; size, grade, and type of material are usually stamped on individual packages (10). This has aided retail merchandising and helped deliver the product in the best condition possible.

Drying Technician Education

The formal phase of operator training remained at a high level. As in 12 of the preceding 13 years, the U. S. Forest Products Laboratory held a 2-week demonstration in the kiln drying of lumber in 1959. One-week short courses were held at the Oregon Forest Products Research Center, the University of California Forest Products Laboratory, the New York State University College of Forestry, and the Canadian Forest Products Laboratories in Ottawa and Vancouver. A Midwest Cooperative short course was initiated in 1958 by Michigan State and Southern Illinois universities. The 1960 session is scheduled for March 21–25 at the University of Illinois, Department of Forestry. Other cooperating agencies for this short course are Iowa State, Michigan, and Purdue universities, and six firms in the drying field. All courses considered, about 125 to 150 kiln operators, yard superintendents, quality control engineers, and other management men concerned with seasoning in the U. S. and Canada received formal training last year.

Informal education is carried on in the 21 dry kiln clubs and associations in the United States. These organizations, with memberships varying from 15 to more than 100, meet from two to six times each year. For the eleventh year, a joint annual meeting was held by the eight western clubs. Another joint meeting was held by the Midwest and Wisconsin–Michigan Wood Seasoning Associations, and a third was held by the Delta, Southeastern Arkansas, and Egyptian Dry Kiln Clubs. Papers pertaining to research and practice in air drying, predrying, kiln drying, lumber storage and handling, and moisture content of wood in use were presented. Panel discussions were held on problems arising from kiln drying and other seasoning operations. Usually one or more plants were visited.

More and more, drying technicians are participating in the meeting programs and are themselves doing a good job in presenting firsthand information on studies they conduct or assist in conducting. These studies cover the practical phases of the drying, storage, and handling fields, i.e., end coating effectiveness, control of stains, drying schedules, stacking, protection of lumber, moisture content of wood in use, and kiln maintenance. The dry kiln organizations contribute greatly toward the production of low-cost, high-quality kiln-dried lumber.

An interesting series of articles for training of kiln operators appeared in a British Journal (16).

Applied Research

Seasoning research of a practical nature, including small-scale experiments of a number of variables in actual seasoning work, pilot tests of most promising procedures, and gathering of data during commercial drying operations, has continued during the past 3 years. Although several fields have been investigated, this review will attempt to cover only two: seasoning of western hardwoods and air drying. The results of applied re-

search already published will be found in other references.

In a pilot test experiment on 4/4 California black oak by Smith (84), both air drying and predrying, followed by kiln drying, were tried. Under summer conditions at Chico, Calif., the lumber yard dried to less than 25 percent moisture content in 9 weeks. There was little difference between 15- and 30-inch pile spacing. In a shed, about 1-½ weeks more drying time were required to reach this same level. Kiln drying, with dry-bulb temperature not exceeding 140° F. until the wettest sample was below 18 percent moisture content, brought the stock to 6 or 7 percent moisture content in another 9 to 10 days. Neither the yard-dried or shed-dried stock had appreciable surface or internal checks affecting grade or full utilization. Predrying was done at two temperatures, 100° and 110° F., and kiln drying subsequent to predrying was started at two average moisture content levels, 30 and 20 percent. These procedures resulted in more defects causing degrade as follows:

Predrier condition	Moisture level before kiln drying	Board footage degraded 1 or more grades
	Percent	Percent
Mild	20	6.0
Severe	20	16.0
Mild	30	25.4
Severe	30	34.4

Many of the severe defects were directly associated with wet areas under the stickers, although some were associated with tension wood and natural characteristics of the species. As a result of the test, Smith recommended air drying 3 to 5 months or predrying about 30 days with a mild schedule, attaining a moisture level of 20 percent, then kiln drying in about 7 days, using moderate conditions the first 3 days. The relationship between tension wood and seasoning defects of California black oak was described by Wahlgren (95).

Bryan (17) reported an experiment on the kiln drying of green 4/4 madrone (*Arbutus menziesii* Pursh.). He recommended a kiln schedule starting at 120° and finishing at 180° F. that dries the wood in 13 to 15 days, including equalizing and conditioning. A reconditioning treatment proved very satisfactory in removing collapse and warping characteristics of this and other dense western hardwoods. Pfeiffer (75) and Ellwood (23) discussed the general problems of drying these and other western hardwoods and recommended suitable drying procedures.

In a semicommercial-scale experiment in southern Wisconsin, Peck (72) air dried 4/4 southern red oak in roofed and roofless piles, some horizontal, some sloped and pitched. Piles were erected four different times throughout the year to determine the effects of the variables and weather conditions on the time to dry the stock to 20 percent M.C. and on the amount of drying defects. All experimental piles were located in an inner row of the yard with at least one shield pile at each end. The time required varied from 65 to 212 days. An average loss in value of $0.73 per thousand occurred, caused principally by degrade of top boards in roofless piles. The low dollar losses were attributed to the test material being of a low grade. A net savings of $0.27 per thousand was obtained by roofing with reinforced water-proof paper. Sloping and pitching had no important effect on drying time, surface checking, end splitting, or loss in value; so horizontal placement of packages is recommended. Least end splitting occurred when the end stickers projected 1 inch beyond the ends of the lumber. Material piled in May, July, and October dried at about the same rate for the first 20 days, but only the May and July piles reached 20 percent in 65 to 75 days. Neither the October nor January piles reached 20 percent before May. A statistical analysis of the surface checking data showed significantly greater checking for October- and January-piled stock than for the stock piled at other times. Checking also was greater in the roofless piles than in the roofed piles, and for the top packages than for bottom and middle packages. Specimens on the edges of the piles also checked more than interior specimens.

Clark and Headlee (20) also showed the economic merit of using pile roofs when air drying oak during both the wet and dry seasons. Advantages in drying rate and uniformity of moisture content were great during rainy spring months. Little degrade developed in the top three courses of roofed piles, but most boards in the same courses of roofless piles dropped one or more grades. The excess of loss in value of the approximately 72 board feet in the top three courses in the roofless piles, compared with the same material in the roofed piles, was $5.19 to $5.47 for No. 1C and Better lumber and $0.87 to $1.87 for Nos. 2C and 3AC. A chart showed the number of 90-day air-drying periods required for roofs of various costs to pay for themselves when used with the different grades of lumber. In general, a $25 roof was shown to pay for itself in 5 periods with No. 1C and Better stock and in 13 periods with the lower grade stock.

Whitmore (97) showed that a small sawmill operator cutting oak can significantly increase the total value of the lumber and his profit by careful air drying. In the study, the net profit increase represented an 8 percent return on the investment in inventory and piling costs.

Page (70) studied the effects of four methods of stacking on drying time, moisture uniformity, and degrade for southern pine during summer air drying in Georgia. There was no significant difference in drying time for the package, crib, and end piles, but the flat hand-stacked piles required about 7 days longer to reach an average moisture content of 18 percent. Moisture content of all boards at the end of drying was measured by moisture meter. Not counting areas under the small stickers used, only 1.4 percent of the package-piled and 2 percent of the end-piled boards were above 19 percent. Hand-stacked flat-piled lumber, however, had 11.2 percent of the pieces above 19 percent, and 95 percent of the crib-piled boards had readings over 19 percent underneath the laps. Moisture content variation, as indicated by standard deviation, was 1.90 for package piling, 2.64 for end piling, 3.68 for flat piling, and 10.29 for crib piling. Average moisture content was 15 percent or below for all except the crib piles, which averaged 22 percent. Average loss per M b.m. was only $3.23, compared with $10.21 in a previous study cited. The author attributed this to shorter time on the yard, 37 days compared with up to 172 days in the earlier study. Blue stain accounted for most degrade, and it was the worst in the hand-stacked piles. The monetary loss per thousand was greatest, however, in the crib-piled lumber.

Benjamin, Combs, Brown, and Johnson (12) have shown that for 1-inch sinker redwood in the slow-drying Humboldt Bay area, more rapid and uniform air drying is achieved by nonuniform spacing between rows of package piles instead of uniform 5-foot spacing. These authors suggest the possibility of using nonuniform spacing during inactive winter months for other species dried in areas where closer spacing would be required during active summer months. Previous studies of yard spacing by Pratt and Clausen are cited. Kotok (54) gives information on the influence of weather on air drying.

Fundamental Research

Fundamental or basic research is research aimed at why things happen whether they are known to be related to any practical process or not. While such research can be aimed at a particular field, such as wood drying, research in related fields also is of inter

to wood driers. The most important event in wood drying fundamentals was the Madison Conference in 1957 (103). The purpose of the Conference was to discuss the status of fundamental information presently known to apply to wood drying and to express thoughts and ideas for possible new approaches of a fundamental nature. Leading figures in the drying of other materials and the use of energy sources not customarily used to dry wood, as well as those engaged in drying or other wood technology research, participated. The ideas brought were not limited to existing concepts of practicality. The fruits of this Conference are yet to come, but meanwhile a considerable amount of fundamental research then in progress has been reported.

A work of major direct importance to wood drying was the development by Youngs and Norris (104, 105) of a mathematical method for calculating drying stresses, in pounds per square inch, employing previously reported fundamentals on drying strains and perpendicular-to-grain strength of red oak. This method, which permits calculating for any point within the cross section the tensile, compressive, and shear stresses, was used to calculate satisfactorily the stresses in a 2-by 7-inch flat-sawed plank after 4 days of drying from the green at 80° F. and 85 percent relative humidity. Though the procedure involves difficult mathematical analysis, the authors believe the method adaptable to electronic computation and likely to provide extensive valuable information in this field, if the basic strain and stress perpendicular-to-grain data are accurately obtained.

Ellwood (24) found the overall stress pattern for 4/4 California black oak very similar to that previously found for 2-inch red oak and generally similar to that for sweetgum, blackgum, and beech. Other references bearing on drying stresses are (44, 47, 51, 58, and 73). An interpretation of drying stresses and sets for kiln operators and others concerned with developing drying procedures (65) indicates how knowledge of these conditions can be used to advantage in developing drying schedules, controlling shrinkage, avoiding seasoning defects, and relieving the final stress-set condition (casehardening).

Information on fundamental wood-liquid relations was published by Spalt (86). Other important papers on this subject have been given in the past few years (19, 101). Research bearing on the permeability of wood and the movement of moisture through it is described in other references (21, 26, 39, 57, 60, 82, 83, 87, 90, 102). A book on drying fundamentals (56) and an article on the mechanism of drying thick porous bodies during the falling rate period (68) are noted.

Seasoning Specifications and Quality Hallmarks

On the background on a long-term trend toward recognizable better quality in lumber products, 1959 marked the year when quality of seasoning became an open controversy among producers of house framing lumber. There were really two controversies: One on using 19 percent moisture content as an average vs. a maximum value (67); the other the maintenance of the right to sell green lumber for house framing vs. the right of housing code authorities to exclude lumber over a specified moisture content.

In 1958 the Southern Building Code Congress adopted a rule amendment stating that house framing members in the cities it serves shall not exceed 19 percent moisture content (6). This action was later ratified by 95 percent of the cities adhering to the code. Grade-marked southern pine conforms to this specification, but there probably is some use of green southern pine lumber not grade marked. The Federal Housing Authority also requires seasoned framing lumber in houses which come under its insurance.

Seasoned Douglas-fir and associated West Coast boards and Dimension are dried to an average moisture content of 19 percent or less with a maximum of 25 percent. In the ponderosa pine region, dried Dimension is about 16 percent and boards about 12 or 14 percent in average moisture content. In all western softwood species, Selects are usually dried to 8 or 10 percent average moisture content, largely because of customer wishes. About 70 percent of the output of Douglas-fir region mills is green lumber. Some of the Dimension lumber from the ponderosa pine region also is unseasoned. The laminating industry, using the Common grades of Douglas-fir and larch, is specifying a moisture content of 12 percent or less because of glue bonding and ultimate use requirements. Knot breakage and planer splitting occurring at the lower moisture values do not affect the bending strength or final appearance of the laminating product.

The term "kiln dried" without a moisture content specification continues to cause trouble to distributors, retailers, and customers in all consuming regions. Many are led to believe that "kiln dried" means the lumber is good but, without a definite moisture specification, they often receive lumber too wet for specific uses. This is particularly true in regions where interior conditions require a moisture content below 10 percent.

This review does not attempt to judge the merits of the controversies or try to indicate their present status. It merely registers that they exist and raises two quetsions: (1) Is the technological information in the field adequate? and (2) What cost factors tend to support the continued production of unseasoned lumber?

On a technological basis, specification of a single value, be it average or maximum, is not enough. Two statistics are needed, one to estimate the average or mean about which most of the values are grouped and the other to indicate in some way the degree of variation. The formal standard deviation or uniformity factor is ideal for this latter purpose so far as accuracy is concerned, but probably too technical for general application at this time. Use of the simpler value, range between maximum and minimum, in conjunction with a definite number of samples tested, is more practical. The single value, maximum, could be impractical because, for strict application, it would require inspection of every piece of lumber in a shipment. Specifications using either the uniformity factor or the range can be set up to outline different degrees of moisture uniformity for different use applications.

In spite of what could be specified as ideal, it should be recognized that some West Coast woods such as hemlock, white fir, and western redcedar, are difficult to dry to final moisture content values within close limits. Under many commercial circumstances, it is almost impossible to have complete sorting of the "heavies" and "lights" into separate kiln charges. Therefore, the range of final moisture content may vary considerably within one charge or even within one board under the limited equalizing procedures permitted by the selling price of softwood lumber.

The redwood industry, under the direction of the California Redwood Association, has launched a program whereby all grades of "Clear all-heart, A grade, Factory Select, and Shop" are now either stamped or stickered with the quality hallmark "Certified Kiln Dried." This certification is obtained by mills employing a form of statistics-based quality control (76). Performance is further checked by Association inspectors who randomly select boards from a pile of dried material and take moisture meter readings. Periodically the moisture

meter readings are checked against ovendry moisture content values. Anderson (2) applied quality control to western pine.

The use of end waxing and end marking has grown widespread, and sale of machines to do the combined jobs has been great in the last few years. For those producers or group of producers who have restricted such marking to properly dried lumber, these marks have become seasoning quality hallmarks. Another type of quality hallmark has been developed by the Wisconsin–Michigan Wood Seasoning Association. For the past 2 years, the Association has awarded "invoice stickers" to member companies who have maintained "active" participation in Association meetings. The term "active" means representation at two or more of the four Association meetings held annually. The object of this plan is to encourage members to attend the meetings as well as to publicize the work of the Association, which includes a kiln inspection service contributing to higher quality drying.

On the matter of cost factors promoting manufacture of unseasoned lumber, the principal items seem to be not total seasoning cost at a going operation, but rather first cost of installing drying equipment or a good yard, inventory and insurance costs, and degrade losses. Various types of wind tunnel and other kilns of low first cost and accelerated air-drying equipment have entered the picture and apparently are paying for themselves in 1 to 3 years. The demand for dry lumber is so great, however, that there are large sales of regular kilns taking longer to pay off. Two major requirements of good air-drying yards, space and drainage, are usually cheap in producing areas, and pile roofs usually pay off in a short time. When properly used, these items greatly reduce drying time and hold inventory and insurance costs comparatively low. Degrade cost has been shown to be small in well conducted seasoning operations on both virgin and second-growth material suitable for ultimate use. Warping of unsuitable material containing excessive compression wood, spiral grain, or juvenile wood is likely to cause expensive degrade under any system of drying, but both state and federal agencies are readily available to assist in utilization problems and divert such material to proper uses. Thus, means appear to be available for producing a larger proportion of seasoned lumber, and it probably will be produced if the real demand for it continues to grow.

Current European Drying Techniques

The use of end coatings to reduce splitting and checking is increasing slightly in Europe. Most suppliers argue that their stock is turned over too quickly to merit end coating. Yards that store thick native oak are showing more than a passing interest, however.

The general seasoning practice for softwoods in the producing areas of Scandinavia, Russia, Poland, and Czechoslovakia is to saw the lumber in the wintertime and put the stock "into stick" for air drying against "first open water" which is normally about May of the following year. Normal conditions of drying are such that stocks are ready for the short sea voyages without any other drying.

All European hardwood-producing countries, including those behind the Iron Curtain, follow the practice of simple air drying for shipped stocks, except for steamed beech. The bulk of hardwoods shipped to the United Kingdom from Europe is kiln dried on receipt. Those shipments made to Middle East oil countries are air dried only before shipment and, because of low humidities in those countries, dry out very rapidly before use. The main shipments to the Middle East are of beech.

In air drying, a higher regard for good sticking of both hardwoods and softwoods is apparent. This is particularly true of Rumania, which supplies large quantities of beech to the United Kingdom, Italy, Spain, and Switzerland. The trend toward light, natural finishes, particularly in Britain, meant high wastage in conversion into furniture because of stick marks under previous practices. Use of softwood sticks and better piling techniques has improved quality to a marked degree. The French practice of shipping beech reassembled in the original log has not been encouraged because distortion, splitting, etc., occur in the ship. Packaged softwoods have been successfully shipped from Scandinavia. This not only aids handling out of the vessels but helps to obtain key sizes and grades without having to take other sizes as well. This practice is peculiar to Scandinavian and Russian shippers. European shippers are reducing the moisture content of softwoods more prior to shipment than during 1958. During 1957/1958, many beautiful Siberian redwood (Scots pine, *Pinus sylvestris*) shipments were completely spoiled by blue stain. During 1959, this form of degrade was practically nonexistent. The year 1959 has been a remarkably dry one throughout most of Europe but particularly in the United Kingdom. Air-dried stocks of hardwoods of 1 inch or less have been down to 8 to 10 percent where normally 15 percent or higher is the rule. This has affected stocks in various ways. Degrade from end and surface checking, particularly in oak stocks, has increased. Conversely, quick-drying woods like abura, obeche, and softwoods, have dried to such an extent as to preclude kiln drying.

Predrying, as a general alternative to air drying, is not practiced in Europe. Denmark, however, uses dry kilns to dry beech to 25 percent moisture content prior to shipment.

In kiln drying, there is a marked tendency for companies owning old kilns to go over to package handling and also to side-loading kilns. This applies to the United Kingdom, Sweden, Germany, and Holland, and to a lesser degree to Belgium and France. Those companies new to the kiln drying field tend to install the cross shaft, end loading, compartment kiln of conventional design. There is a definite trend in the United Kingdom toward higher air speeds and higher temperatures (or lower relative humidities) on certain species found to be tolerant of these conditions. Automatic devices for reversing the fans at shorter intervals of about 30 minutes instead of 12 or 24 hours are also being installed more frequently, practicularly with quick-drying species. Also, installations using coal or oil as fuel are tending to be provided with automatic damper control to reduce heat losses. Kiln drying in the Balkans, where beech is a staple exportable timber, is very much in its infancy, and kiln-drying technique is of a crude nature. Yugoslavia and Rumania steam a large amount of beech to produce a red type of material.

Drying in steam at temperatures above boiling point *in the absence of air* (superheated steam drying) has been almost abandoned, even on the Continent. There has been a slight increase in the number of small electrically heated kilns installed in situations where electricity can be bought at a low rate at night. Although drying is longer because of daytime cooling, such driers have proved an economic devise for small manufacturers. Drying by electronic means has not had extensive economic success. It is considered in Europe that the use of R.F. heating for the drying of wood will remain limited.

While the standard of kiln operation is high, in Great Britain at least there is no formal training of kiln operators or dry kiln clubs such as found in the United States. Interest in this type of activity is growing, how

r. Relatively few seasoning studies h e been made and published. Much what has been done has been the k of research laboratories. Man- turers are becoming more critical quality in relation to kiln-dried k, but, generally speaking, no real mpts have been made at quality trol or proper analysis of kiln dry- In Paris, the Centre Technique Bois has produced a "Cashier des ges: des sechoirs a bois" in an at- pt to bring some standardization drying specifications for wood with ticular regard to customer require- ts. This has been of some assist- in reducing degrade.

The use of water-repellent coatings wood surfaces is gaining ground ng joinery manufacturers and the lding trades, but progress is slow.

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Review of Chemical Utilization[1]

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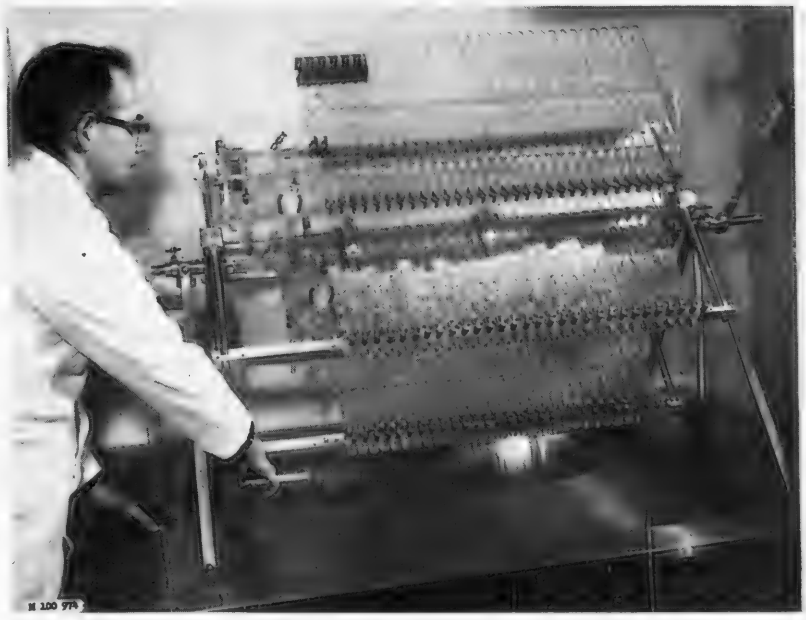
Complete literature surveys on the chemistry of lignin and wood extractives . . . Comprehensive reviews on bark and bark extractives . . . Plus sections on pulping, charcoal, and wood hydrolysis.



The Craig Apparatus is used for counter-current separation of extractives.

Pulping

CHEMICAL UTILIZATION OF WOOD by the pulping industry was featured by the installation of additional continuous digesting systems, two-stage pulping processes, progress in spent sulfite and neutral sulfite semichemical pulping liquor recovery, and expanded use of mill residue chips.

A continuous down-flow method of making neutral sulfite semichemical pulp was put into operation in Sweden (191). Carlsmith, Rasch, and Dhus described the installation of a continuous up-flow process for making neutral sulfite semichemical pulp (135). The largest continuous digester in the world for making kraft pulp was put into operation (44) and plans for still larger installations were mentioned (32). A new system for the continuous production of cold soda pulp was described (39).

A new bleached sulfite pulp produced from pine by a two-stage pulping process is now available. In the first stage the wood is impregnated and the lignin partly sulfonated with a slightly acid liquor; the second stage involves the removal of lignin at a lower pH (40, 192). The production of prehydrolysis sulfate pulp from pine of both dissolving and paper grades was expanded (41).

Brown, Jackson, and Tongren described six methods of recovering chemicals from neutral sulfite semichemical pulping spent liquor (113). These and other processes for recovering spent acid and neutral sodium sulfite pulping liquors were discussed in other publications (42, 43, 192). The problems involved in the production and profitable utilization of the carbohydrates in spent sulfite liquor were reviewed by Wiley, Whitmore, and Boggs (635). The separation of the lignosulfonate and the sugars in spent sulfite pulping liquor by ion-exchange resins was reported on by Felicetta, Lung, and McCarthy (199).

Pascoe, Buchanan, Kennedy, and Sivola reported on extensive pulping tests on various species of wood by single- and multi-stage sulfite digestions and on the influence of sodium thiosulfate in the cooking liquor (475). Dorland, Leask, and McKinney extended their investigations of pulping with sodium bisulfite to include hardwoods (175). Marth examined the sulfonation of lignin in pulping by the sulfite process over the range of pH 4.5 to 9 (411). Ingruber studied wood and wood constituents as acid-buffering systems in sulfite pulping (317). Rydholm and Lagergren investigated the delignification reactions in sulfite pulping from kinetic and lignin-chemical viewpoints (527).

Freedman reported on improvements in the strength of hardwood soda pulp when produced by a two-stage process using sodium carbonate in the first stage and caustic soda in the second (206). The cold soda pulping of oak, sweetgum, and cottonwood for pulps suitable for use in printing paper as a substitute for softwood groundwood and for making corrugating board was discussed by Brown (112). The investigations of Stone and Green revealed that the movement of cooking chemicals into hardwoods is quite different from the movement into softwoods. Liquids penetrate hardwoods mostly through the vessels, the fibers contributing little or nothing to liquid flow, and the movement of chemicals into the fibers and middle lamella is solely by ionic diffusion (585).

Five authors reviewed methods of handling mill residue chips in the West, including truck and rail transportation (205, 395), chip compaction (273), weighing and dumping (209), and chip specification standards (519). The development of residue chip utilization in the South was presented by Baker (60) and Parnell (474).

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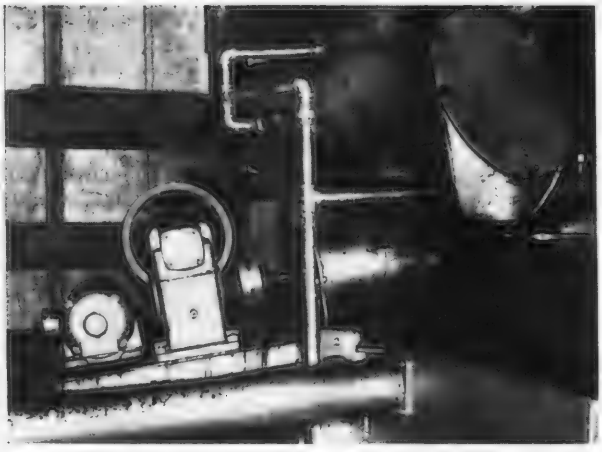
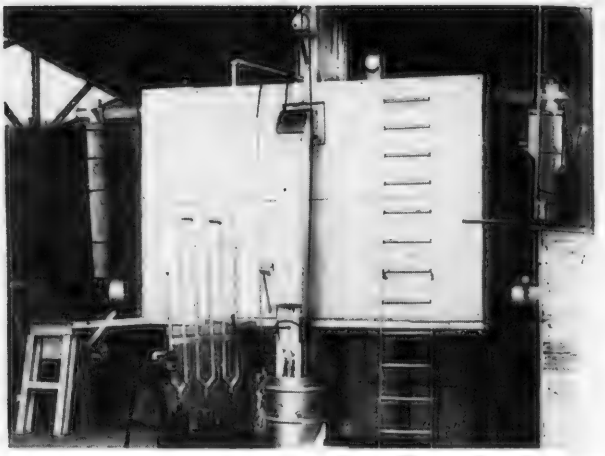
[2] Numbers in parentheses refer to the Literature Cited at the end of this review.



Continuous carbonization (265): Exit tube conveys carbonized residue to vat prior to briquetting (lower) or to storage bin (center). Steam spray cools and activates charcoal.



Back end of carbonizer shows bypass of gases to dutch oven, drive for charcoal leaving carbonizer, and experimental fractionating device for collecting wood distillates. (165)

Developments in Charcoal Production

Interest in charcoal remains at a high level from the standpoint of both recreational consumers' demand and new and expanded developments for its production. Coincident with both has been the desire for a quality evaluation procedure specifically for charcoal. Most of the present methods for the analysis of charcoal are based on ASTM methods for coal and coke, with inclusion also of various modifications. A procedure to qualify as a possible standard method for charcoal analysis is being developed at the Forest Products Laboratory. It is designed to provide accurate results for amounts of moisture, volatile matter, ash, and fixed carbon. Method evaluation on standard samples is being conducted at representative laboratories for comparison of results prior to submission of the method for ASTM Committee review.

Trend to Continuous Conversion: Positive steps paralleling the indicated need for additional charcoal production facilities are apparent with the more recent developments in this field. One comparatively large operation employing a standard procedure that utilizes only process reaction heat for continuous conversion of chips fed through vertical retorts (35, 446) has been recently reactivated for full production. Anticipated charcoal output will be about 70 tons of briquettes a day.

A further establishment of trends toward continuous production is evidenced by an informal report of a commercial operation based on radiant heat as a means for continuous conversion. The chip fines are carbonized as they travel on an endless belt over electrically heated platens. A continuous 3-inch layer of chips subjected to a temperature of about 700°F. travels over the active bed for a predetermined period of retention time. The carbon fines produced have a natural outlet to briquetting facilities at an adjacent location.

A further example of the suggested operational trend to continuous conversion is provided in a recent development involving adaptation of horizontal tube conversion (165). Processing is conducted within a brick and concrete structure. A single metal tube equipped with a screw conveyor carries various types of wood fines to a hopper for equal distribution to horizontal tubes mounted across a direct heating or combustion chamber. After it has passed through these carbonizing tubes, the charcoal is discharged to a single exit tube for transport to storage chambers. The over-all structure includes a dutch oven at the lowest level, which supplies duct-carried heat to an upper chamber containing the carbonization tubes. In operation, the dutch oven is fired for an initial period of several hours to obtain a preprocessing temperature of about 850°F. After carbonization is underway, the wood gases are diverted from the carbonizing tubes to the dutch oven for combustion. Continuation of the process is accomplished by heat supplied from this latter source only. Complete plans for future operations include production integrated with briquette production. Along a similar path of emphasis toward continuous charcoal conversion, Canadian production (38) is presumably well underway at a multiple-tube operation based on cedar waste as the raw material. Adjacent sources of mill residues will provide raw material to this British Columbia carbonization plant, which is reported to be the largest on the Pacific Coast.

Use of Ammonium Chloride: Recent studies conducted in Japan (350) report substantial increase in charcoal yields from kilns by use of dry ammonium chloride. The salt is introduced periodically during the coaling cycle and results in charcoal yields 15 to 20 per cent above normal. Chlorine is present in the bark and wood charcoals to the extent of 0.16 and 0.02 per cent, respectively.

The noticeable build-up of consumer preference for briquettes has provided, in at least one state, a type of kiln structure somewhat uncommon but reportedly affording satisfactory production to briquette plants that are closely associated. Specific reference can be made in this case to units chiefly of reinforced concrete arch-roof construction that on the average hold about 45 cords of wood each. It is not known whether the aforementioned capacity indicates optimum economic amounts of charcoal per charge, or a design limitation toward structures of larger size.

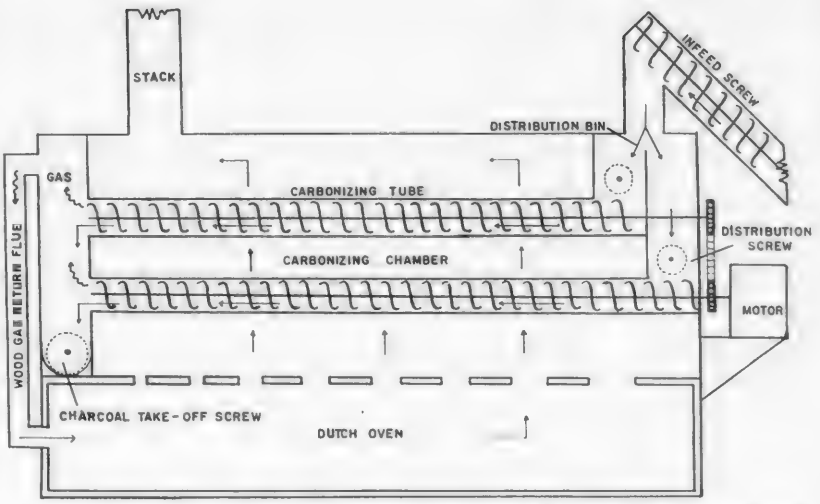
The latest in a series of four articles (278, 279, 280, 281) by Hanzawa and Satonaka employing a dehydrating agent as a means of wood carbonization has been recently published. Low temperature carbonization by controlled action of concentrated sulfuric acid or phosphoric acid has been found to yield charcoal comparatively low in carbon but highly effective as a decolorizing material.

Wood Hydrolysis Processes and Products

Wood saccharification and its associated and derived products called forth a considerable amount of research effort during the year. As in past years, the Russian workers were especially active in this field. Fractionation of the total carbohydrate content of wood residues by selective removal of a pentosan-rich hemicellulose cut was one of the main research goals. The use of a water prehydrolysis at temperatures

n the neighborhood of 190°C. gave od recovery of pentosan in the form furfural (320). Changes in the mposition of wood constituents dur-g water hydrolysis and the kinetics of ntosan removal were determined 12). A patent on the selective sac-rification of wood residues by the e of two-stage hydrochloric acid drolysis was issued (48). Equipment the continuous hydrolysis of wood a commercial basis was described 55, 552). With 76 per cent sul-ric acid as the hydrolyzing medium, ystalline glucose yields of 300 kilo-rams per ton of wood were reported (155). The mother liquor from the acose crystallization served as the arting material for the production of glycerol, alcohol, or yeast; the spent sulfuric acid going into the production of phosphate fertilizers. Further work on two-stage processes was concerned in one case with the use of low wood-to-acid ratios (1:0.3) of 15 per cent sulfuric acid in the primary hydrolysis and slightly higher ratios of 30 to 60 per cent sulfuric acid in the secondary hydrolysis (332). In the second case (654), primary and secondary hydrolyses were done with hydrochloric acid and the residue autofermented to yield a fertilizer and soil conditioner. Furfural was considered as the high-value product. The advantages of high hydrolysis temperatures (553), of the use of ball milling to promote hydrolysis with small amounts of concentrated sulfuric acid (454), and of sugar decomposition inhibitors (649) were investigated. Improvements in the "Rheinau" process were discussed (536) as was the purification of hydrolyzates by ion-exchange columns (5). Hydrolysis studies of a more fundamental nature were also reported (355, 405).

The kinetics of the formation of furfural from xylose solutions and the influence of processing variables such as acid concentration, xylose concentration, additives, and temperature were the subjects of two intensive studies (521, 554). Pre-extraction with organic solvents was shown to give more uniform conversion of wood pentosan to furfural and to provide a 3 to 5 per cent increase in yield (558). This effect was attributed to reduced tar formation. A patent was granted for a continuous process for the production of furfural and acetic acid from vegetative material (443) and a pilot plant to evaluate the Skog-Säve process is reported under construction in Japan (277). The preparation of hydroxymethylfurfural from cellulosic materials was given patent protection (568) and the first commercial production from wood waste under license of this patent was announced (568).



Continuous carbonization (165): Flow chart of layout for carbonization of fine wood residues.

Cash awards for potential commercial product ideas regarding levulinic acid were bestowed in a "Big Idea" contest (34). Suggestions included use as a starting material for phosphorus-containing compounds, surface-active agents, lubricating oil additives, and drugs. Major current use is as the raw material for diphenolic acid, an intermediate in the production of a class of synthetic resins (25). Antibiotics may be produced via a chloro-derivative (557). A study of the recovery of the high sugar content from larch butts by an extraction process is underway (29) and a description of the current status and research trends regarding utilization of spent sulfite liquor carbohydrates was given (635).

Thermal Degradation—Hydrotropic Solution—Miscellaneous: Levoglucosan, the major product obtained from the dehydration of cellulose under controlled thermal degradation conditions *in vacuo*, received renewed interest during the past several years, apparently as a source of polyhydric alcohols (546). Studies of the reaction mechanisms (245, 246, 247, 248, 548, 553) showed that the dehydration progresses through two stages. In the initial stage, cellulose chains are split at regular intervals until a limiting D.P. of about 200 is attained (248). This is accomplished by dehydration and rearrangements such that the fragments are of high density. In the final stage, these high-density fragments are converted by isomerization of the glucose residues into levoglucosan (1–6 anhydro 1–5 glucopyranose). Formation of levoglucosan requires an intact structure in the elementary units and yields vary directly with the so-called packing density (247). Yields of 55 to 60 per cent are obtained from a pure cotton cellulose but only 4 to 5 per cent from a rayon. Glucose alone yields only 5 to 6 per cent levoglucosan, about the same as cellobiose and the addition of glucose to a cellulose prior to degradation causes a considerable drop in yield (246). The latter result was explained as due to inhibition of the isomerization process by a blocking (by glucose) of the radicals formed during the earlier stages of decomposition. In the production of levoglucosan from wood waste, an acid prehydrolysis (2.5 per cent sulfuric acid at 100°C.) is advantageous since pentosans were shown to be inhibitory (546). This feature is covered by a patent (544). Yields of about 30 per cent, based on cellulose were obtained by heating the prehydrolysis residue for 30 to 40 minutes at 320°C. in a vacuum or in an atmosphere of carbon dioxide or hydrogen. Reactions and products from the thermal degradation of isolated hemicellulose, mannan, xylan, and holocellulose were also investigated (174, 545, 548) as was the relative influence of oxygen and nitrogen on the nature of the reaction (402). Polymerization of levoglucosan into high molecular weight branched polysaccharides was accomplished through chloracetic acid catalysis (537).

Developments in the Chemistry of Lignin

This review is a continuation of that included in last year's "Review of Chemical Utilization," I. A. Pearl and A. S. Gregory, Forest Products Journal 9:85(Feb., 1959).

Model Compound Studies: The use of model compounds in the study of the chemistry of lignin has continued to a limited extent. Juslen and Enkvist (330, 331) synthesized a number of sulfur-containing model compounds for thiolignin and determined their ultraviolet and infrared absorption spectra. Freudenberg and co-workers (216) compared thioglycolic acid lig-

nin with model compounds by the direct titration method and found the method suitable for determining the number of phenolic hydroxyl groups. Ishizu and co-workers (318) studied a number of model compounds with relation to alkaline cooking of wood and concluded that a part of the condensation of lignin during such cooking occurs by carbon-carbon bond formation between position 5 of the phenolic nucleus and the alpha-position of the side chain. Pearl (479) reported the preparation, R_f value in two solvent systems and infrared absorption spectra of 25 lignin model compounds in the phenylpropane series. Other studies with lignin models were in the field of biosynthesis.

Studies on Biosynthesis of Lignin: Investigations on the biosynthesis of lignin have continued at a rapid pace and many papers appeared during the year. Kratzl and Faigle (366) injected coniferin (3–C^{14}) into 2-year old spruce branches, and measured the distribution of the radioactivity in the wood, bark, side shoots, and extracts. Incorporation of the coniferin was very rapid compared to the implantation method employed in earlier studies. Wacek and co-workers (229) tested the effect of adding coniferin or propioguaiacone-*d*-glucoside to tissue cultures of a number of plants *in vitro* and found that coniferin enhanced lignification in some cases, but propioguaiacone glucoside did not. Neish and co-workers have continued their studies on lignin biosynthesis employing isotopic carbon. C^{14}-labeled aromatic compounds having side chains of varying length and substitution were fed to cut stems of wheat, buckwheat, sedge, spangle-top grass, *Salvia splendens,* and maple (642). Lignin was isolated and radio assays were made after 24 hours of absorption. C_6-C_1 was utilized poorly and C_6-C_2, not at all. Experimental results with C_6-C_3 compounds were consistent with the view that lignin monomers are synthesized through 2-hydroxylated phenylpropane intermediates. Similar studies (115) with phenylalanine, tyrosine, *p*-hydroxyphenyllactic acid, and *p*-hydroxyphenyllpyruvic acid were made on cut stems of wheat, buckwheat, and *S. splendens,* and the plant tissues were analyzed for phenolic aldehydes and hydroxycinnamic acids. Phenylalanine was found to be a lignin precursor for all species, but only wheat was able to convert *p*-hydroxyphenylpyruvic acid or *p*-hydroxyphenyllactic acid into syringyl and guaiacyl parts of lignin. Possible biosynthetic pathways are discussed. Similar studies employing degradation of the lignin by hydrogenolysis instead of oxidation (114) gave essentially similar results. However, labeled sinapic acid which is converted to lignin yielding syringaldehyde, did not form lignin degradable to dihydrosinapyl alcohol by hydrogenolysis. Thus, the active syringaldehyde was shown not to arise from sinapic acid bound to lignin with alkalilabile linkages. McCalla and Neish (397, 398) reported studies on the metabolism of phenylpropanoid compounds in *Salvia* and showed that shikimic acid is an excellent precursor of phenylalanine and tyrosine and that experimental results on the biosynthesis of phenolic cinnamic acids were compatible with the biosynthetic sequence cinnamic–>*p*-coumaric–>caffeic–>ferulic–>sinapic acid.

Freudenberg and co-workers continued studies on the enzymatic dehydrogenation of coniferyl alcohol. It was found (214) that peroxidase plus hydrogen peroxide has the same effect on coniferyl alcohol as does laccase plus oxygen and that the initially formed mesomeric radical becomes stabilized by formation of various dimeric quinone methides. The formation of a guaiacyl glycerol ether has been explained by the addition of water to a quinone methide. In the presence of aqueous methanol, sorbitol or sucrose, the dehydrogenation of coniferyl alcohol yields ethers corresponding to the alcohol in addition to the guaiacyl glycerol ether (213). Similar ethers are formed by manganese dioxide dehydrogenation of coniferyl alcohol in the presence of these alcohols. The authors suggest that these experiments demonstrate the nature of the lignin-carbohydrate linkage. Dehydrodipinoresinol has been identified as one of the products of enzymatic dehydrogenation of coniferyl alcohol (215). On methylation and oxidation, this compound yielded dehydrodiveratric acid (not formed from pinoresinol itself) indicating that the compound is a diphenyl derivative. The authors suggest that the formation of this diphenyl derivative furnishes one of the most important points at which, during continuous dehydrogenation, pinoresinol condenses with itself and with other lignin-building blocks. In addition, Freudenberg (210, 211, 212) has published three reviews of the work of his group on the structure of lignin.

Kreitsberg, *et al.,* (368) subjected *Populus trichocarpa* trees approximately 3 feet in height to radioactive carbon dioxide for 24 to 72 hours and then allowed them to assimilate in air for 30 days. Radioactivity determinations were then made on the leaves, various parts of the stem, and the lignin and its degradation products. Results indicate that the methoxyl groups originate from early lignin precursors and not from methylation of lignin molecules, and suggest that the formation of the side chain is a secondary process. In other studies (547) in which radioactive pentoses and α-D-methylglucoside (C^{14} in methyl) were injected into 4-month old seedlings of the same species, results indicated that pentoses are good lignin precursors and that the methoxyl group of the methylglucoside is not utilized for lignin methylation. In a study of the changes of the contents of lignin and other chemical constituents with growth of Yugao fruit, Tachi and co-workers (590) found that the gradual increase of methoxyl content during lignification supports the hypothesis that lignin is formed by transmethylation from a precursor of the cinnamyl alcohol polymer type.

Prey and Szabolcs (499) transformed 6-desoxyhepturonic acid into *p*-hydroxybenzoic acid *in vivo* with formation of cyclic intermediate products resembling shikimic acid. These authors concluded that other aromatic hydroxy acids which can be isolated from lignin by fusion with alkali might be formed in a manner analogous to shikimic acid.

In a comparison study of the chemistry of lignification of *Eucalyptus regnans* and *Pinus radiata,* Bland and Greet (92) examined the cambium scrapings of the two woods and found the Klason lignin content and the yield of aldehydes on oxidation of the material from *E. regnans* were close to those of the wood whereas these values for the material from *P. radiata* were much lower than those from the wood. Hillis and Carle (309) collected the cambium of *E. regnans* and *E. sieberiana* at different times during spring and summer and submitted them to paper chromatography. These investigators found that the major recognizable components, (+)catechin, (—)epicatechin, (—)epigallocatechin gallate, shikimic acid, corilagin, β-glucogallin, and three hydrolyzable tannins, did not change with progressive growing season and discussed the origin of polyphenols in woody tissue. They also suggested that methylation of lignin precursors takes place in the cell wall. Mugg (435) extracted the lignifying tissues of *Populus tremuloides* with methanol and examined the extracts by chromatography to find phenylalanine, tyrosine, serine, glycine, and sinapaldehyde in the new xylem. No evidence for suggested lignin precursors such as shikimic, ferulic, and sinapic acids, coniferyl alcohol, coniferaldehyde, and syringin could be found in the differentiating tissues of aspenwood. In a study of the lignin content of the strengthening tissue of a number of hardwoods, Klauditz (351) reported morphological measurements and

hemical analyses which indicated that positive relation exists between the gnin content of hardwood strengthning tissue and the proportion which ie compound middle lamella occupies the cell wall. Kratzl and Buchtela 365) submitted a mixture of coniryl alcohol and sinapyl alcohol 3–C^{14}) to enzymatic dehydrogenaon with mushroom laccase and obained a DHP resembling that obtained rom coniferyl alcohol alone and in hich the sinapyl alcohol was incorrated in such a way that ethanolyzble structural elements of the β-aryl her type were obtained. Relationships the biogenesis of angiosperm lgin are discussed. Reviews on biosynhesis of lignin have been presented y Gierer (232) and by Nord and Schubert (451) who also considered he isolation and structure of lignin, and by Kremers (369) who reviews recent lignin literature from the standpoint of the plant physiologist and the biochemist.

The Lignin-Carbohydrate Bond: The nature of the linkage between lignin and carbohydrate in wood has been given attention. Lindgren (390) studied the lignin-carbohydrate complex, milled wood lignin, and the aqueous dioxane-soluble portion of milled wood lignin of Norway spruce by electrophoresis on glass-fiber sheets. His results indicated that at least a great part of the wood lignin is linked to hemicellulose. McPherson (400) fractionated milled sprucewood by successive extraction with dioxane, dimethylformamide, dimethylsulfoxide, and water, and submitted his fractions to further fractional precipitation and chromatography. This investigator obtained a series of lignin-carbohydrate complexes along with relatively pure lignin and hemicellulose fractions. In a study of the chemical combination between the lignin and carbohydrate components of wheat straw, Hayashi and Tachi (288) obtained by paper chromatography a compound (xylolignin) consisting mainly of xylose and lignin. Ultraviolet absorption curves and difference curves on acetylated xyloligin, dioxane lignin, and their saponification products led these authors to assume a phenol-glycosidic bond in wheat straw xylolignin. Lindgren (391) reviewed recent research in this field and suggested that the oxygen bridge of β-phenyl glycosides or of benzyl ethers are the most favored linkages between lignin and hemicellulose in wood. In studies on the adsorption of lignin and hemicellulose of straw on cellulose, Centola and coworkers (137, 138) concluded that ligneous tissues contain a lignin-xylan complex.

Functional Groups in Lignin: A number of investigators have considered the reactive groups in lignin. Adler and Marton (7) reduced a number of aldehydes and ketones of the guaiacyl propane series to the corresponding alcohols by means of sodium borohydride, studied the reactions spectrophotometrically by the $\Delta\epsilon$ procedure, and compared results with those obtained with spruce milled wood lignin. Results indicated the following distribution of carbonyl units per methoxyl group in milled wood lignin: phenolic coniferyl aldehyde, less than 0.01; etherified coniferyl aldehyde, 0.03; phenolic 4-keto-guaiacol group, 0.005-0.01; and etherified 4-ketoguaiacol group, 0.05–0.06. These authors also concluded that an approximately equal amount of isolated keto groups may be present in the β-position of the propane side-chain. Gierer and Söderberg (235) compared volumetric methods for carbonyl determination in lignin model compounds employing sodium borohydride and hydroxylamine and found that only the borohydride method gave consistently accurate values. Determinations on Brauns' and milled wood lignins indicated 0.41–0.48 carbonyl groups per methoxyl group for the borohydride method and 0.12–0.19 for the hydroxylamine method.

Adler and co-workers (6) applied the sodium periodate method for guaiacyl groups containing free phenolic groups to Brauns' lignin and milled wood lignin from various softwoods. They found the proportion of guaiacyl residues having a free phenolic group for Brauns' lignins to be approximately 0.45 and for milled wood lignins to be about 0.30. Slow liberation of methanol was noticed from all lignin preparations in contrast to the rapid liberation observed with almost all lignin model substances. Eckman (181) investigated the nature of strongly acidic groups in lignin isolated by digestion of sprucewood with sodium hydroxide at 100–170° by means of titration, methylation, reduction, and infrared and ultraviolet absorption studies, along with comparative studies of ethanol lignin and seven lignin-model compounds. Data suggested that the major portion of the strongly acidic groups of soda lignin are true carboxyl groups located in the aromatic structure of lignin. Ultraviolet-absorption and $\Delta\epsilon$ data supported the concept that carboxyl groups are linked directly to benzene nuclei, and infrared spectar indicated the presence of esterifiable carboxyl groups, as well as conjugated and isolated carbonyl groups. Studies on ethanol lignin indicated no strongly acidic groups even after alkaline hydrolysis and no free or esterified carboxyl groups. Mazen-

Micro-distillation under vacuum.

Papier (418) oxidized with nitrobenzene and alkali the tissues from germinating plants of representative softwoods and hardwoods and chromatographed the oxidation products. He noted that the appearance of aldehyde spots coincided with the development of a positive Mäule reaction. Aulin-Erdtman (57) reviewed ultraviolet absorption changes caused by modifications of chromophores and application of the $\Delta\epsilon$ method to the study of the groupings in lignins. Gierer (233) also reviewed the reactive groups known or suspected to be present in wood lignin and their most important reactions.

Mechanism of Pulping Reactions: Studies were continued on the reactions taking place during pulping operations. Tishchenko (597) reviewed the condensation reactions between phenols and aldehydes and discussed the condensation relative to inactivation of lignin during the sulfite cook. Because sulfonation of phenols or their ethers prevents the condensation reaction, Tishchenko concludes that, during the sulfite cooking of softwoods, two competing reactions occur: condensation, favored by low pH, and sulfonation. Whether "inactivated" lignin or soluble lignosulfonates are obtained will be determined by the relative rates of these two reactions. The buffering action of bisulfite favors the sulfonation reaction. Chudakov (149) criticized Tishchenko on the grounds that sulfonated lignins are not analogous to aromatic sulfonated phenols. He suggested that sulfonation increases the solubility of the lignin condensation products, but does not inhibit condensation. Tsypkina and associates (607) studied the inactivation of lignin by water prehydrolysis and subsequent pulping with sulfite liquor at 105°. Under such conditions, carboxyl groups are formed by breaking of carbon-carbon condensation bonds. No such car-

boxyl groups are produced if wood is cooked under normal sulfite conditions without water prehydrolysis. Kleinert and Dostal (352) isolated spruce lignosulfonates from sodium bisulfite cooking liquors after various cooking times and studied their chemical properties and ultraviolet absorption spectra. All lignosulfonates were found to be carbohydrate-free without exception. With increasing cooking time, the carbon content of the lignin was found to increase, although the combustion factor and methoxyl-carbon ratio were both found to remain practically unchanged. The sulfur content of the lignosulfonates dissolved from the wood in the first stage of cooking was found to be higher than that of the sulfonates from liquors with extended cooking time. Brickman, Cabott, and Purves (102) sulfonated a carbohydrate-free spruce periodate lignin for various times at pH 5 and 100°, conditions known to cause only minor condensing and hydrolytic effects. The resulting series of insoluble sodium lignosulfonates were subjected to autohydrolysis in water for 2 hours at 135° to give nearly quantitative yields of soluble lignosulfonates. Results obtained in this investigation confirmed by a direct method the Kullgren-Hägglund two-stage theory of sulfonation. Since wood holocelluloses were absent, the chemical phenomena of sulfonation did not depend on the cleavage of any lignin-carbohydrate bonds that might be present in wood.

Marth (411) pulped aspenwood chips by sulfite-bisulfite cooking liqours of initial pH 4.5, 7.2, and 9.0 for varying lengths of time under otherwise constant conditions. The relationships between pulp yield, lignin content, sulfur content, aldehyde yields on nitrobenzene oxidation of pulp and liquor, and position of sulfonated and unsulfonated lignin residues in the partially cooked chips were compared for the various conditions.

In the study of the chemistry of soda and kraft pulping, Karlivan and Odintsov (336, 337) cooked milled pinewood at 150° for different times in both soda and kraft liquors. Pulp yield increased with increasing sulfidity. The content of acidic groups in the residual lignin was approximately the same in all cooks. Partial saponification of methoxyl groups in the solid-phase lignin caused increased lignin solubility and more methoxyls were split off in kraft cooks. The incorporation of sulfur during kraft cooking occurred stepwise, so that the lignin solubilized in the initial stage contained less sulfur than the lignin solubilized in the later stages. Condensation of lignin and saponification of methoxyl groups reduced vanillin yields from the solid-phase residual lignins. The chemical changes taking place in the lignin during these alkaline cooks were investigated by taking samples of the cooking liquor at different times and precipitating with acid. Higher lignin yields were obtained from soda than from kraft cooks. Yields of lignin decreased with increased cooking, but the Klason lignin value of the lignin increased. The carbonyl content of lignin, especially kraft, decreased during the cooks, and the methoxyl contents of the black liquor lignin were lower than those of the lignin remaining in the solid phase. Alcohol-soluble lignin fractions were characterized by high Klason lignin contents and high acidic hydroxyl contents. The alcohol-insoluble fractions contained mostly carboxyl and carbonyl groups. Kukhnikova (373) studied the mechanism of the kraft cook by cooking periodate lignin with kraft liquor. Maximum solubilization took place with a sulfidity of 25%. Demethylation and the formation of carboxyl and phenolic groups increased with increasing temperature and prolonged cooking time. Letonmyaki and Komshilov (383) analyzed black liquors from two kraft mills, carried out at different cooking stages and found that, under the influence of alkali, oxidation-reduction and dehydration reactions occur in the hydroxyl-containing side chains of lignin, which lead to the formation of enol groups and acids.

Sobolev and Schuerch (570), in continued studies on hydrogenation pulping, showed that the lignin obtained was a relatively simple mixture of distillable phenols and thermoplastic resins, and the pulp was somewhat lighter than soda pulp. These authors suggest this lignin as an attractive starting material. In other studies on the alkaline hydrogenation of sugar maplewood, Schuerch and co-workers (79) isolated from the lignin fraction *p*-hydroxybenzoic, vanillic, syringic, guaiacylacetic, guaiacylpropionic, and syringylpropionic acids. They also obtained evidence that catechol and pyrogallol derivatives may be present in the liquor.

Hydrotropic lignin from aspenwood was studied by Gromov and Odintsov (272) who obtained three lignin fractions during stepwise cooking with 36% sodium xylenesulfonate. These fractions had different methoxyl and phenolic hydroxyl contents and different solubilities in alkali, bisulfite, and other solvents. All fractions had an aromatic character.

Lignin Isolation: A number of papers appeared on the isolation of lignins from wood. Chochieva and Nikitin (146) found that the yield of dioxane lignin from oakwood was not increased by removal of hemicelluloses with alkali or degrading them with *Polyporus sulphureus* although the carbohydrate content of the lignin was reduced. The purest lignin was obtained without the use of hydrochloric acid and from decayed wood. Bland (88) demonstrated that long grinding of *Eucalyptus regnans* in methanol in a vibratory ball mill yielded only 7% more lignin on the lignin basis. Countercurrent distribution studies (86) on eucalypt lignin indicated a general structure similarity with spruce lignin. Chromatographic examination (85) of methanol lignin of *E. regnans* indicated three substances recognizable as lignins together with a number of degradation products. Vanillin and syringaldehyde were definitely identified, and sinapaldehyde was tentatively identified. Absorption spectra were determined for lignins separated chromatographically from methanol extracts of *E. regnans* specimens taken along a line from pith to bark (87). The procedure produced two lignin fractions; one of these was substantially the same from any position between pith and sapwood, the other apparently changed progressively from pith to sapwood. The bark lignins of several hardwoods and several softwoods were studied by Hata and Sogo (284). Alkaline nitrobenzene oxidation followed by chromatography showed the presence of guaiacyl, *p*-hydroxyphenyl, and 3,4-dihydroxyphenyl, but no syringyl buildings units in the inner and outer bark of softwoods, whereas all four types of building units were present in the inner and outer bark lignins of the hardwoods. Kratzl and co-workers (91) treated extracted sprucewood with methanol or ethanol at 150° in the absence of mineral acids to obtain alkylated lignins. Studies with labeled methanol and with beta-guaiacyl ether of guaiacylglycerol indicated that alkylation of lignin occurs at the benzyl alcohol group. Demethylation of radioactive lignin by the Zeisel procedure yielded only a part of the radioactivity as methyl iodide, and the authors concluded that the methanol entered the lignin partly with formation of stable carbon-carbon bonds.

More studies were reported on the separation of lignin from and the fractionation of spent liquors of commercial pulping operations. Uyeno and Kitaura (611) precipitated lignosulfonates from spent sulfite liquor by addition of calcium hydroxide and found carbohydrate materials in the precipitate. Herscu (304) separated lignosulfonates from spent sulfite liquor by precipitation with calcium hydroxide. McCarthy and associates (199) separated substantially the lig-

nosulfonates and carbohydrates of spent sulfite liquor by ion-exchange resins. Buevskoi and Sapotnitskii (120) increased the amount of lignosulfonate precipitable from spent sulfite liquor by means of sulfuric acid by adding acetaldehyde, furfural, or glucose. Schwabe and Schmidt (539) employed chromatographic and thermodiffusion techniques for fractionation of lignosulfonic acids in chemically unchanged form. These authors also demonstrated that mill effluents can be oxidized catalytically in a relatively short time without formation of toxic phenolic compounds by means of special mixed catalysts containing iron, copper, manganese, and platinum. Tsypkina and Balashova (606) precipitated lignosulfonates completely and specifically from spent sulfite liquor with complex metal salts such as hexammine cobalt chloride or nitrate. These authors found 67.7% of the methoxyl groups in the precipitate from spruce spent liquor and assumed that the rest of the methoxyl groups were bound to the carbohydrate components of the spent liquor. Höye (312, 313) described a process for fractionating ammonia-base spent sulfite liquor solids by means of fractional treatment with alcohols and adjustment of pH to obtain several lignosulfonate and carbohydrate fractions. Jantzen (324) separated high and low molecular weight lignosulfonates from each other and from spent sulfite liquor by contacting the liquor with finely divided chrome-tanned hide to combine with the high molecular weight lignosulfonates.

A pressure carbon dioxide method for the precipitation of lignin from black liquors is described by Giesen (237). Bogomolov and Sokolova (95) show that removal of 10–15% lignin by precipitation from black liquor does not affect the course of the chemical recovery process. Field and co-workers have studied the organic chemistry of sulfur in the kraft process. A commercial pine kraft lignin was subjected to fractionation by stepwise acidification and chromatography (201) and was shown to be a mixture of many substances, which demonstrated distinguishing differences, but considerable general similarity. Studies with Raney nickel and alkali (200) indicated the presence of about four different types of sulfur linkages, and methylation studies indicated that the commercial kraft lignin may consist of about one unit of alkali lignin with two units of sulfur-containing lignin. Further studies on fractionated kraft lignin (179) indicated that the kraft process markedly modifies groups in lignin responsible for color reactions. These studies also suggest that no thiol, thiocarbonyl, disulfide and polysulfide linkages are present in kraft lignin.

Apparatus for fractional distillation (center).

Lignin Analysis: Interest has continued on the determination of lignin and lignin materials. Jayme and co-workers (325) have published the final improved version of the Jayme-Knolle method for the determination of lignin in extractive-free cellulosic materials. The method, employing a mixture of 6 volumes of 75% sulfuric acid and one volume of 89% phosphoric acid takes much less time than does the 72% sulfuric acid procedure and gives values which agree with those found by the Halse method, but lower values than those found by the 72% sulfuric acid method. Kurschner (371) reviewed the subject of the determination and outlined a nitric acid procedure for the simultaneous analysis of cellulose and lignin in untreated woods. Details of this alcoholic nitration procedure have been published along with lignin values for various woods (372). Grohn and associates (271) have shown that apparent lignin values of milled samples obtained by the conventional 72% sulfuric acid method are dependent on the degree of disintegration in the vibratory ball mill. Every degree of milling has a corresponding optimum reaction time with sulfuric acid to obtain a minimum lignin yield with a maximum methoxyl content.

Physical Chemical Studies: Several papers appeared on the physical chemistry of lignin and lignin derivatives. Kanda and Kawakami (334), in continuing their work on the polarography of lignin, found that soda lignin produces a well-defined catalytic wave in ammoniacal cobalt buffer and gives the same wave as do lignins containing thiol or persulfide groups such as thiolignin. Grimsrud and McCarthy (270) measured the friction factors and heat-transfer coefficients of magnesium-base spent sulfite liquors for steady-state pipe flow at concentrations up to nearly 60% solids and at wall temperatures in the range of 200–260°F. The fluid was found to be Newtonian and to give the usual Fanning friction factors within the range investigated. The physicochemical properties of sulfate pulp chlorolignin were studied by Løschbrandt and Wetlesen (394) and the possible bearing of their observations on the reactions taking place during the alkaline-extraction stage of kraft pulp bleaching was discussed. Goring and Rezanowich (254) sulfonated periodate lignin in stages by a series of short bisulfite cooks. At each stage the soluble lignosulfonate was removed and purified, and the residue was resulfonated. Fractions were studied by physical chemical methods. There was a marked increase in both the intrinsic viscosity and rate of solution with increase in reaction time. The fractions had constant methoxyl contents and ultraviolet absorption coefficients, but there was a gradual sulfur content increase with increased integral reaction time. Goring, Webb, and Sehon (255) subjected lignosulfonate fractions to free-boundary electrophoresis and found that lignosulfonates removed from the sulfonation mixture as soon as they became soluble were homogeneous in spite of appreciable differences in sulfur content and intrinsic viscosity. On prolonged heating, heterogeneity appeared. Ingruber

(317) studied the weakly acidic nature of wood and preparations of cellulose and lignin and compared them with the behavior of a conventional chemical buffer system by means of sensitive pH measurements. The author explains their acid character by the concept of hydrogen-ion availability rather than by conventional acid-base terminology. Odintsov (456) investigated the water-vapor sorption by cuprammonium lignin and by a biolignin prepared by degradation with the mold *Coniophora cerebella* and concluded that the structure of the capillary system of a lignin depends upon the method of lignin preparation. Bland (90) chromatographed the methanol lignins from *Eucalyptus regnans* and *E. goniocalyx* tension wood and compared the two fractions obtained with those obtained from normal wood by means of ultraviolet absorption spectra. Tension wood lignins resembled those from the outermost portions of the heartwood. Butler (128) discussed the applications of infrared spectroscopy to lignin characterization and Gardon and Leopold (227) demonstrated the use of paper chromatography at different pH values for characterizing lignin oxidation products.

Vanillin Production: The production of vanillin from lignin materials has been given considerable attention this past year. Sobue and Saito (571) precipitated lignosulfonates from spent sulfite liquor with lime and subjected the relatively pure lignin material to alkaline reaction under pressure with and without the presence of oxidizing agents. Best results were obtained with nitrobenzene. Sukhanovskii (587) suggested that sodium hydroxide consumption in the production of vanillin could be lowered by removing calcium from vanillin spent liquor and using the resulting sodium sulfate solution for further vanillin production with much less added sodium hydroxide. Pushkareva and Grigor'ev (503) reported the production of vanillin in yields of up to 20% by oxidation of hydrolysis lignin or sawdust with cupric oxide and relatively little alkali. Other work on the production of vanillin from sawdust or spent sulfite liquor by means of alkaline solutions of cupric oxide are described by Kreitsberg, Odintsov, and Sobolevskii (367). Atanasiade and Ille (56) oxidized wood with alkaline nitrobenzene. Alberda (9) reported the extraction of vanillin from alkaline oxidation mixtures with organic bases such as isopropylamine, diethylamine, morpholine, and pyridine and Kamaldina (333) described a procedure for the precipitation of vanillin from mixtures as the bisulfite-addition compound. Sokolova, Baranova, and Nazar'eva (574) noted that good yields of vanillin could be obtained from black liquor lignins if the original pulping process was carried out under conditions preventing extensive degradation. Limiting conditions were 140° and 30 minutes at maximum temperature. Best results were obtained with cupric oxide. Karlivan, *et al.*, (338) subjected a series of thiolignins from pine to alkaline nitrobenzene oxidation and established a direct relation between sulfur content of the thiolignin and the concentration of sodium hydrosulfide in the original cooking liquor. The yield of vanillin obtained on oxidation decreased as sulfur concentration increased.

Chemical Properties: Chochieva and Nikitin (145) studied the dioxane lignin from oak, spruce, and fir and found them to be similar in chemical composition to lignins extracted with concentrated acids. Crude dioxane lignin was shown to be a lignin-carbohydrate complex containing 75% of the total wood lignin, 72–80% of its hemicelluloses, but no cellulose. The carbohydrate material could be removed from the crude product by hot water extraction. Pepper (490) reviewed the present status of knowledge of the chemistry of hardwood lignins with particular emphasis on those aspects of the problem wherein further research is indicated. He suggested that much of the knowledge of the fundamental chemical composition must result from a study of chemical changes and extrapolation rather than by absolute measurement. Stanek (580) subjected extracted aspenwood to water at 170° and examined the hydrolysis liquors by means of chromatography and countercurrent distribution. Vanillin, coniferyl aldehyde, syringaldehyde, sinapaldehyde, *p*-hydroxybenzoic acid, vanillic acid and syringic acid were isolated and identified as hydrolysis products. Successive hydrolyses of the same wood yielded additional amounts of these products and results indicated that these compounds were derived from aspenwood lignin. In an attempt to locate the positions of the sulfonic acid groups in lignosulfonic acids, Smith and Purves (565) refluxed spruce periodate lignin with aqueous sodium bisulfite and subjected the product to autohydrolysis with boiling water. This product was treated with chlorine dioxide to yield oxylignosulfonic acids and oxylignins, but no aliphatic sulfonic acids. More than half of the original sulfonic acids were recovered as sulfuric acid. Gierer and Alfredsson (234) treated thiolignins from Brauns' lignin and from milled wood lignin with neutral sulfite solutions to obtain lignosulfonic acids with all sulfur in the form of sulfonic acids and the amount of sulfonic acid groups corresponding to that calculated under the assumption that one sulfide group was replaced by two sulfonic acid groups. Sulfonation of thiolignins in acid media was less complete. The authors concluded that the same reactive groups participate in both the sulfidation and sulfitation reactions of lignin. Gaslini (228) sulfomethylated kraft lignin with formaldehyde and sodium bisulfite and then sulfonated the product with sodium sulfite to give a completely water-soluble product which was evaluated as a tanning agent. Sobolev and Schuerch (569) examined the volatile fraction of white birch soda lignin and obtained a combined yield of less than 2% of acetosyringone, acetovanilione, syringaldehyde, vanillin, syringic acid and vanillic acid. In addition they obtained gas chromatographic evidence for *p*-cresol, guaiacol, 4-ethylguaiacol, and 4-ethylsyringol or 4-vinylguaiacol. Ultraviolet absorption spectra and refractive indices suggested the presence of phenols with alpha beta-unsaturated side chains which may be reactive intermediates in delignification. Enkvist and co-workers (184) treated various lignin materials with ammonia under pressure in an attempt to prepare anion-exchange resins, but all attempts were unsuccessful. Arlt and Schuerch (50) studied the ethanol spruce lignins prepared in chloroform-ethanol and concluded that the ethanol lignin fractions studied were branched fragments cleaved from a larger polymer. Nikitin and Obolenskaya (449) oxidized alkali lignin with oxygen and alkali and found that the ether oxygen and carboxyl contents increase, and acid degradation products, such as formic, acetic, and oxalic acids, and carbon dioxide are formed.

Hydrolysis Lignins: Lignins obtained by the hydrolysis of cellulosic materials have been given considerable attention, especially by Soviet investigators. Schoenemann (536) has reviewed the Willstätter procedure for wood saccharification and has described the improved Rheinau process for saccharification of wood or other cellulosic materials. He suggested uses for the activated lignin by-product. Krasnova, Sukhanovskii, and Chudakov (364) activated hydrolysis lignin by heating with alkali and demonstrated that a large proportion of the aromatic groups present in the hydrolysis is

split during alkaline treatment even at temperatures as low as 180°. The lability of protocatechuic acid groups in hydrolysis lignin—about 80% of which are split during alkaline activation—indicates that they are linked to the basic heterocyclic complex by a simple ether linkage. In further work, Chudakov and co-workers (150) subjected milled hydrolysis lignin and two alkali-activated lignins to oxidation with potassium permanganate. Yields of benzene polycarboxylic acids were 2.4% from the hydrolysis lignin and 3.0 and 25.2% from lignins activated with alkali at 180 and 270°, respectively. These results are interpreted as evidence for the existence of a basic condensed aromatic ring structure in the lignin molecule. Panasyuk (467) solubilized cotton-hull and wood hydrolysis lignins by heating for varying lengths of time at 360–400° under pressure with anthracene oil or petroleum. Best solubilization results were obtained with petroleum. Zarubin and Tishchenko (650) treated Scholler lignin from softwood with 5–15% aqueous sodium hydroxide for 2 hours at 270–285° and obtained a mixture of phenolic products having molecular weights of 360–400. The yield of ether-soluble products exceeded 50% of the lignin weight. Giesen (239) hydrogenated Scholler lignin in xylenol over a ferrosulfate catalyst to obtain phenolic materials. Panasyuk (468) compared yields obtained by degrading cotton-hull and wood hydrolysis lignins by means of heating in vacuum, dry distillation, and thermal solubilization. He showed that the pyrolysis method influences the yields of tar and phenols, but has no effect on the composition of the products obtained. The nature of the products is dependent upon the starting material. Panasyuk and Maksimenko (469) prepare activated carbons by thermal decomposition of cotton-hull hydrolysis lignin. Sergeeva, Chuksanova, and Shorygina (543) treated purified hydrolysis lignin with dilute nitric acid and obtained 2,3-dinitroguaiacol and oxalic acid in the products. Other work (321) on nitration of hydrolysis lignin with concentrated acid gave nitrated products with nitrogen attached to aromatic rings in the ratio of one nitrogen to one guaiacylpropane unit in lignin. Tishchenko (598) ozonized spruce Scholler lignin in ethyl acetate to give a triozonide having a molecular weight of 180 and containing one benzene ring. Decomposition of the ozonide under controlled conditions to give oxalic acid indicated 100% aromacity of the lignin. Studies on sprucewood indicated that during ozonization, the free lignin of the middle lamella reacts first, whereas the less accessible lignin-carbohydrate complex of the cell wall reacts with ozone in the second stage. Shorygina and coworkers (560, 561) converted the insoluble and relatively inert hydrolysis lignin into a soluble and reactive compound by chlorination. These authors describe several methods for accomplishing the chlorination and characterize the chlorolignins obtained.

Lignin Utilization: Many studies and patents have appeared on the utilization of lignin-containing materials. One scientific-technical meeting was held on the utilization of spent sulfite liquor and lignin (36). Giesen (236, 238) decomposed lignin into distillable products by hydrogenation over a ferrosulfate catalyst. Doughty and Cook (177) obtained chlorinated lignin from the alkaline-extraction stage in pulp bleaching systems by precipitation with aluminum sulfate.

Resins have been prepared from lignin by condensation with phenol (47) and from spent sulfite liquor by condensation with aldehydes (257) or by treatment with ammonia (256). Lignin and lignosulfonates have been polymerized with furfural and a secondary aromatic amine to give resins (589) and lignin has been employed as an extender in diisocyanate-linked elastomers (447). Adhesive binders have been prepared from spent sulfite liquor by heating with sodium hydroxide and furfural (610).

Much use has been made of the physicochemical properties of lignin and lignosulfonates in utilization processes. Surface-active agents have been produced by treating spent sulfite liquor with an alkylene carbonate (430) or with ammonium compounds (290). Lignosulfonates have been studied in cement mixes (427) and have been used in Portland cement compositions (74) and in hydraulic cement mixtures (541, 399). Spent sulfite liquor has been mixed with titanium ores and carbonized to yield titanium dioxide (596) and as a binder in the preparation of iron ore briquettes (161) and foundry molds and cores (623). Lignosulfonates have again been used extensively in drilling mud formulations (116, 129, 130, 594, 595, 627, 628, 629, 630) and cyanoethyl ethers of lignin have been proposed for use in coating compositions and drilling muds (621). Oil well cementing compounds have been prepared from spent sulfite liquor (431, 609), and spent liquor has been employed for road stabilization (18, 207, 208). Soil improvement materials have been prepared from spent sulfite liquor (134, 195) and spent liquors have been used in the preparation of pesticidal compositions for spraying plants (230). Lignin has found a number of applications in the rubber industry for reinforcing rubber (423, 496, 502), for redispersing rubber (341), and for introducing water into vulcanizable rubber compositions (269). New tanning agents containing lignosulfonates have been reported (414, 542), and fertilizers have been prepared from lignin (176). Other uses reported for lignosulfonates include mold nutrients (353), ignition composition for matches (382), preparation of lignoborate salts (204), slime prevention (188, 566), dispersion of carbon black pigments (619), dispersion of paper-sizing suspensions (498), tinting bath for photographic papers (94), and in aluminum etching solutions (514). Reaction of kraft lignin with formaldehyde and a primary or secondary amine gave a product which inhibits corrosion of iron and steel by acids (61).

Distillation process (foreground); separation of extractives in chromatographic column (rear).

A number of reviews have appeared during the past year covering the chemical utilization of lignin (84, 289, 477, 484, 615).

Bark

In 1957, Marian and Wissing completed a thorough and extensive bibliography entitled, "The Utilization of Bark I. Index to Bark Literature" (406). Reprints are available from the Swedish Forest Products Laboratory, Stockholm, for Sw. Crowns 14:–. In this section as well as the following one on the extraneous constituents of wood and bark, an effort has been made to include the major references to bark utilization and chemistry that have appeared since 1955 when Marian and Wissing concluded their bibliography. However, material that has been mentioned previously in the "Review of Chemical Utilization" is generally not repeated.

Several general papers have appeared discussing the utilization (22, 72,

Plant equipment layout for the All-Board Process (14). (Photo courtesy Blaw–Knox.)

428, 612, 638) and properties of bark (422, 658). A recent literature survey on bark adhesion and removal might also be worth mentioning (491). A book entitled "Bark" has been published, but it deals mostly with descriptions of bark (540).

The biggest use of bark today is as a fuel. In many cases the fuel value is either wasted or merely used to dry the bark. However, there have been a number of recent publications dealing with multiple-fuel-firing steam generators that can efficiently and economically use even hydraulically removed bark (28, 123, 221). The Canadians have been particularly successful in this respect and two meetings have been held recently on this subject (76, 494).

Another potential outlet for bark is as a soil conditioner or as a mulch (59, 96, 180, 241). In the former case, the bark must be either fortified with additional nitrogen or composted. A number of companies are marketing balanced bark soil conditioner-fertilizer amendments as well as orchid rooting mediums. This use of bark is quite analogous to the similar use of sawdust, shavings, and wood chips in the soil, and the pertinent literature should be consulted. Bark, as well as other wood waste, can even be used for growing mushrooms (93). Among the articles in a recent issue of the Forest Products Journal devoted to bark utilization were several dealing with the use of bark in the soil (322, 396), including the novel suggestion that the bark could be used as a filter for cannery or sewerage effluents prior to its incorporation into the soil (127). The Vermont Bureau of Industrial Research is also very interested in the utilization of bark (532), and they have investigated its use as an animal bedding, mulch, composted soil amendment, potting material, fuel, and in lightweight cement. They have a utilization report available.

Another potential outlet for bark involves its incorporation into various types of building boards, and an increasing amount of interest is being shown in this possibility (12, 14, 386, 442, 458, 516). The fibrous fractions of bark are particularly suitable for this purpose, and two recent papers detail some rather encouraging results (73, 408). A recent patent deals with the separation of sclerenchyma fibers from Douglas-fir bark (298). The corky fraction of bark is also valuable for these purposes (125, 297). The Canadian Forest Products Laboratory at Ottawa is studying the use of hemlock and jack pine barks in insulation and hardboards. They are also evaluating the alkali extracts of spruce and balsam-fir barks in particle-board adhesives.

The polyphenol and tannin fractions of bark are receiving considerable attention. A large outlet for this fraction is in oil well-drilling muds, and a number of patents have been issued covering this and related fields (266, 311, 385, 421, 505, 506, 603, 613, 614). The polyphenols and condensed tannins which will precipitate with formaldehyde can also be used in various type of adhesive formulations (23, 301, 302, 407, 439). Although these polyphenols and tannins can often be extracted merely with water (517), bisulfite, alkalies and similar reagents are often used in order to increase the yield or improve the quality of the product. Extraction with alkali can also lead to other products of potential value (121, 122, 194, 299, 657). Another patent deals with the alcoholysis of bark to produce a mineral-free polyphenol fraction (16).

Other interesting developments include the destructive distillation of bark (75), and studies that have been carried out on the chemistry of bark lignin (284, 295, 572). A number of publications and patents have appeared dealing with the utilization of redwood bark (21, 127, 385, 420, 495, 643). The use of paper mulberry bark to make tapa cloth has been discussed (26).

Extractives of Wood and Bark

Last year, the section on wood extractives in the "Review of Chemical Utilization" discussed the importance of extractives and initiated a thorough survey of the progress in wood extractives covering 1957 and 1958 (484). This year, the survey on wood extractives is brought up to date, and in addition, that data on bark extractives from 1955 to December 1959 are included which have not appeared in previous "Reviews of Chemical Utilization."

A number of recent review articles have discussed the chemistry and utilization of extractives (171, 190, 196, 307, 637). In addition, two recent books of interest have been written. One on the cell wall contains sections on extractives, bark, suberin, etc. (602), while the other is a survey of the occurrence of natural products (except alkaloids) in the plant kingdom (339). A number of meetings of interest have also taken place. The proceedings of a symposium on phytochemistry (24) include not only a number of interesting original papers, but also an excellent survey and bibliography covering the Far East, Australia and New Zealand. The proceedings of the IVth International Congress of Biochemistry, Vienna, were published early in 1959 (45). Volume I, entitled "Carbohydrate Chemistry of Substances of Biological Interest," included chapters on hemicelluloses and plant gums. Volume IV, entitled "Biochemistry of Steroids," included a chapter by Djerassi on plant steroids and related substances. Most important was Volume II, entitled "Biochemistry of Wood." Although most of the chapters discussed lignin, and several others discussed polysaccharides, there was an excellent chapter by Erdtman, entitled "Conifer Chemistry and Taxonomy of Conifers," and others by Sandermann and Stanley on the biogenesis of terpenoids, and by Grisebach on the biosynthesis of anthocyanins. A symposium on wood chemistry was also held June 18, 1959, in Seattle as part of the Pacific Northwest Regional Meeting of the American Chemical Society. Among the papers were those on the constituents of Pacific silver fir (*Abies amabalis*) bark by Hergert, acetates of dihydroquercetin by Aft, acid hydrolysis of hardwood extractives by Pearl, *et al.* (480), plicatic acid from western red cedar

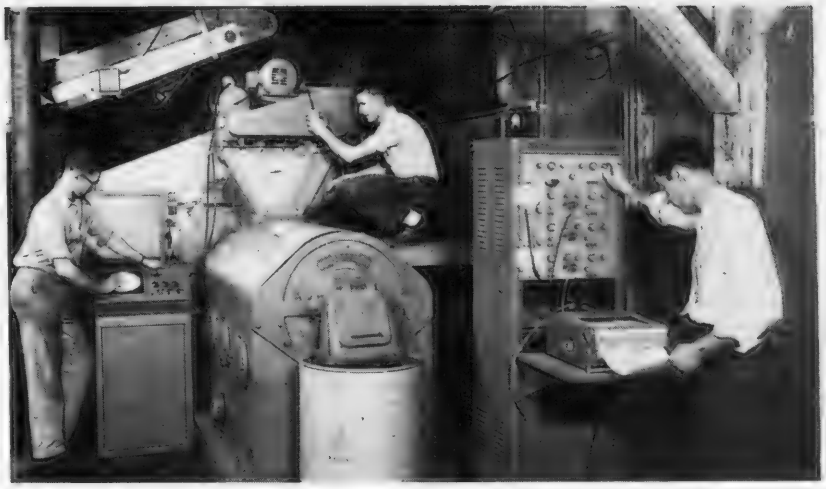
by MacLean, *et al.* (226), tropolones from *Cupressaceae* by Zavarin, *et al.* (652), and the solvent seasoning and extractives of redwood by Anderson (13). Other papers covered bark, hemicellulose, cellulose, iron stain in wood, etc.

A large number of general papers have appeared. The effect of water-soluble (445) and alcohol-benzene-soluble (409) extractives on the shrinkage and moisture content of wood has been studied, as has the effect of extractives on the modulus of rigidity of veneers (147) and on the rigidity of gelatin gels (440). Surveys have been made on the fatty acids of American pulpwoods (118), hardwood resin (436), the occurrence of inositol derivatives (13, 19, 493), and the occurrence of sterols, tannins and flavanols in the bark and other parts of various trees (622). Erdtman has published further reviews on conifer chemistry and taxonomy (45, 187), and Pearl has continued his researches on hydrolysis of the polar extractives and of the wood of various hardwoods (45, 478, 482). Acid hydrolysis has thus shown that vanillin and syringaldehyde as well as the corresponding acids are indeed present as well as glycosides and esters. In an interesting related study, Pearl has also examined the products of hydrolysis of the trunks of 26 different palms (481). Surprisingly, *p*-hydroxybenzoic acid was extremely common.

The wax content and composition of barks have been reviewed (624), and an article has discussed the vitamin content of barks (639). The simple sugars in tree barks in relation to cold resistance and seasonal variation have been discussed (473), as has the extraction of pentosans from woody tissues (97). Conifer barks as a source of commercial tannins have been discussed (1), and the ability of tannins to protect ferrous metals, even when in the soil, has been the subject of a most interesting article (354). Calcium oxalate crystals in coniferous wood have also been investigated (522). Chemical analyses of the wood and bark of 95 Philippine species have recently been made (429). There has also been an increased interest in terpenoid derivatives. One recent review discussed the cadinenes and cadinols (300), while another reviewed the biosynthesis and interrelationships of nonterpenoid natural products containing isoprenoid units or the related furano ring system (17). Briggs, *et al.* (107) have succeeded in interrelating a number of naturally occurring diterpenoid hydrocarbons and elucidating their absolute configurations.

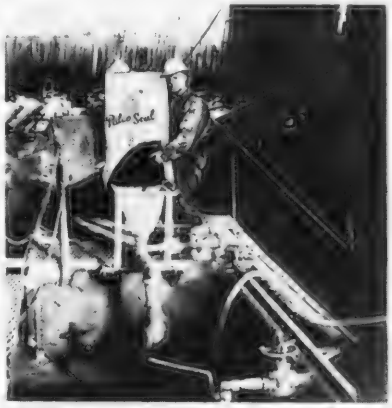
Considerable recent attention has been given to the biosynthesis of polyphenols, especially those of higher molecular weight. The biosynthesis of a large group of natural products including tannins, lignans, some phenolic extractives and even lignin via phenoldehydrogenative coupling has been discussed recently (68, 655). A theory on the biosynthesis of hydrolyzable tannins from carbohydrates has also been published (631). However, most of the interest has been on the polymerization of leucoanthocyanins (308, 524) and catechins (218, 415, 417) to condensed tannins. Several recent reviews have appeared on flavanoids (217, 634) and leucoanthocyanins (152, 524, 551). Especially noteworthy is a recent review by Seshadri on flavonoids, which includes tables of occurrences, biogenesis, physiological importance, and commercial uses (549). Rodd (520) includes a succinct section on flavanoids as well as on hydrolyzable and condensed tannins. The leucoanthocyanidins from some Indian barks have been studied (380), and Roux (525) has reported a superior method of producing anthocyanidins from the leuco derivatives.

Turning first to the genus *Pinus*, there has been considerable recent interest in the tannins from pine barks (1, 20, 203, 242), especially by the Australians who have thoroughly investigated the tannin from *P. radiata* bark (98) and are experimenting with the use of this material in adhesive formulations. The distribution of leucoanthocyanins in different parts, including the wood and bark, of 44 different pines has been investigated (370). All of the barks contained both leucodelphinidin and leucocyanidin, while the wood contained only the latter. Hergert has recently patented his process for producing myricetin from lodgepole pine bark (296). The chemistry of Scotch pine wood and bark has been investigated, especially in regard to the effect of the extractives on the inclusion of these materials into hardboards (14, 15). The water-soluble polysaccharides of loblolly pine wood have been investigated (329), and the phenolic extractives of *P. pumila* heartwood have been studied (361). The composition of the oleoresins from *P. nigra* var. *caramanica* (*pallasiana*), *P. halepensis* (*pithyusa*), and *P. cembra* var. *sibirica* have also been studied (63).



Modified screw press removes 92 percent of dissolved solids from redwood bark (643).

Although it is definitely not the purpose of this review to cover the voluminous literature on tall oil, the fact remains that the constituents of tall oil by and large represent extractives that were originally present in the wood (usually pine). Therefore, a few leading references to recent developments and reviews would indeed be appropriate. The Institute of Paper Chemistry has come out with an even more recent edition of their excellent bibliography on tall oil (626), and a tall oil symposium (37) and an excellent recent paper on tall oil (169) have recently appeared. This latter paper not only gives a considerable amount of production information not previously available, but also a rather complete chemical analysis of Arizona Chem-



Oilwell drilling fluids are controlled with bark additives (420).

Removing bark by hand is a two-man job in the redwood region.

ical's tall oil. Other recent papers have dealt with various analyses of tall oil (276, 303, 359) as well as the isolation (117) and proof of structure (538) of palustric acid. The naval stores and tall oil industries have been compared (67) and the production and processing of tall oil discussed (66). An excellent review article is entitled "Fatty Acids from Tall Oil" (476), and the possibility of producing pharmaceutical-grade sterols from tall oil pitch is receiving considerable attention (142, 151, 582). The Tall Oil Association has printed an excellent series of bulletins on the uses for tall oil fractions. Tall oil from *P. densiflora* has been found to contain a variety of interesting neutral substances including several sterols, lignoceryl alcohol, terpenoids and, surprisingly, *cis*-stilbene (319).

Considerable research has also been carried out on other members of the *Pinaceae* family. In the genus *Abies* there have been several interesting developments. The Ivory Pine Co. has discussed its schemes for the utilization of true fir bark (202, 322). The cork from white-fir bark has been investigated (193, 294), and *A. lasiocarpa* cork bark has also been studied (342). Siberian fir bark oils (488) and wood resins (403) have also been examined.

As expected, a considerable amount of research has been carried out on Douglas-fir, especially the bark. Kurth is continuing his research on this material, and Weyerhaeuser has patented a new process whereby the bark is treated with hot alkali to produce a polyphenol fraction plus a high yield of a superior wax (299). The production of quercetin and dihydroquercetin from this bark are already well-known developments (30, 268, 374). The distribution and variation of dihydroquercetin in Douglas-fir and western larchwood have been studied (30), and a method has been worked out for the spectrophotometric determination of quercetin (178). Incidentally, quercetin and its glycosides have some antibiotic properties (344). The bark also contains eriodictyol (315). It has been found that Douglas-fir bark cork can be made into good floor tile (125). The presence of the extractives is necessary in order to obtain a good bond. The Canadian Forest Products Laboratory at Vancouver is currently studying the polymeric leucoanthocyanin in the sapwood.

In the genus *Picea* most of the recent interest has centered around the spruce bark tannins (81, 265, 376, 392) which are a commercial product in Russia. Water rafted or chemically debarked bark is found to be deficient in tannin. The polysaccharides in the tannin extracts have also been investigated. Further stilbenes, related to those Grassmann has previously found in the tannins, have been reported (183), and a stilbene derivative has also been found in spruce sulfite liquors (656). Spruce bark has also been mentioned as a source of dyestuffs (583). Other investigations on spruce bark include one on *P. Abies* (14) and a paper on *P. glauca* (466). Additional studies have included spruce resin (62, 356), *P. sitchensis* wood extractives (357), and the chemical composition of knotty and malformed sprucewood (497).

In the genus *Larix,* most interest has centered around the water-soluble arabogalactans which are commonly found in good yields in these woods (3, 55, 100, 329). The Russians have been especially interested in this material from *L. gmelini* (*dahurica*), and have extensively studied its distribution, chemistry, and utilization (605). The oleoresin from *L. decidua* (64) and *L. gmelini* (489) has been studied, and the flavonoids of normal and abnormal heartwood of *L. kaempferi* have been examined (222). The botany and chemistry of *L. decidua, L. leptolepis,* and *L. gmelini* have been discussed (647), and the composition of the bark oils from the last two species analyzed (220).

In the genus *Tsuga,* mountain hemlock (*T. mertensiana*) bark has been analyzed (375), and the polyphenols from western hemlock bark are finding increasing commercial application (627), especially as a result of Rayonier's research program.

In the *Cupressaceae* family, most of the recent interest has centered on the analysis of the tropolones and related heartwood extractives, usually by paper chromatography (224, 387, 620, 652). Two new tropolones have been found: β-dolabrin in western red cedar (*Thuja plicata*) heartwood (224), and pygmacin from *Cupressus pygmaea* (652). Chamaecin from the essential oil *Chamaecyparis taiwanensis* was shown to be an ether of thujaplicinol (388). The structure of the sesquiterpenoid, viridiflorol from *Juniperus oxycedrus,* has been elucidated (173), as have the structures of the new aromatic sesquiterpenoids, cuparene and cuparenic acid, isolated by Erdtman from several different species (185). A review on the extraneous substances of incense cedar *(Libocedrus decurrens)* has been published (651). The Canadian Forest Products Laboratory at Vancouver is continuing their studies on the polyphenols of western red cedar, and especially plicatic acid (226). Gardner and MacLean have found that high-temperature seasoning increases the paintability and color stability of this wood by oxidatively fixing the polyphenolic extractives. Normally, these are water soluble and migrate to the surface during drying whereupon the pyrogallol groups undergo oxidation. The utilization of western red cedar residues, extractives and bark has been discussed (633).

From other genera, a vast number of unusual and exotic compounds have been isolated, usually from the bark. One very common type of compound is the triterpenoid which is often present in the form of saponins. Among the species in which both new and known triterpenoids have been found and investigated are: *Trochodendron aralioides* bark (644), *Sideroxylon pohlmaniamum* bark (156), *Siphonodon australe* bark (157), *Styrax japonica* bark (559), *Quillaja saponaria* bark (156, 453), *Prunus nepalensis* bark (65), *Phyllanthus emblica* bark (380), *Psidium guajava* bark (52), *Minusops heckelii* (156, 349, 528), *Mora* spp. (156), *Leptospermum* spp. bark (155), *Hovenia dulcis* wood (591), *Emmenospermum alphitonioides* wood (156), *Euphorbia* spp. latex (250), *Dictyoloma incanescens* bark (464), *Castanospermum australe* wood

(156), *Ceratopetalum apetalum* 326), *Albizzia anthelmintica* bark 604) and *Barringtonia racemosa* 24).

Pistacia spp. resin (gum mastic) nd galls contain a series of triterpe- oids including some new tetracyclic cids (69,508). Betulinic acid appears o be very common in *Platanus* spp. eartwood and bark (462, 645); a ew flavanol has also been isolated rom *P. acerifolia* bark (462). The riterpenoid, cycloeucalenol from *Euca- yptus microcorys* wood (159) has also een found in *Erythrophloem guine- nse* (158) and *Swietenia mahagoni* 11) heartwoods. Melaleucic acid, one f the triterpenoids from *Melaleuca* pp. barks, has been found to contain he interesting feature of a C-10 car- oxyl group (51). Structure studies on he novel triterpenoid derived anti- iotic, pristimerin from *Pristimera* spp. woods and *Celastrus* spp. root barks, re being continued (264). The struc- ture of the biogenetically significant triterpenoid, *alnusenone* from *Alnus glutinosa* bark, has been elucidated (578). This bark also yields a crystal- line tannin glucoside (167). *Kopsia* spp. barks contain not only alkaloids such as kopsine (24), but also triter- penoids (83), including the new com- pound, bauerenol, which possess a rearranged ursene skeleton. This com- pound is also found among the *Acronychia baueri* bark triterpenoids, and the structure elucidation was car- ried out on material from this source (378). It is possible that ilexol iso- lated from the *Ilex* spp. bark triter- penoids (646) is a mixture of baueren- ol and the corresponding heteroannu- lar diene. *Ilex* spp. bark is also the source of the antimalarial drugs ilex- anin A and B (148). The structure of hydroxyhopanone, another of the un- usual triterpenoids from *Dipterocarpus* spp., has been confirmed (198), and the structures of two new triterpenoids, dammarenolic acid from *Dipterocarpus* spp. and nyctanthic acid from *Nyc- tanthes arbor-tristis,* have been eluci- dated and found to be quite usual ex- cept that both have the previously un- known 3:4-seco-$\Delta^{4(23)}$-ene-3-carboxylic acid feature formed by the opening of ring A (49).

Dipterocarpus spp. yield consider- able amounts of a highly autooxidiz- able oleoresin. Ourisson (461) has studied the taxonomy of this material in many members of this genus. In all cases he finds the triterpenoid, dipter- ocarpol, usually quite pure. The re- mainder of the oleoresin consists of a mixture of sesquiterpenes. Some α-gur- junene is present in practically every case. γ-Gurjunene is sometimes pres- ent as well as one or another, but not both, of the two isomeric aromaden- drenes. β-Gurjunene is only found in commercial samples of the oleoresin which have been contaminated with material from other genera. The struc- ture of the biogenetically significant sesquiterpenoid, drimenol from *Drimys winteri* bark, has been elucidated (110), and the structure of the sesqui- terpenoid, maaliol from maali resin *(Canarium samonense),* has been de- termined and its synthesis carried out (119). This compound is also found in *Valeriana officinalis.* Ledol has been isolated from *Phebalium squamens* bark (377).

Another class of compounds which are very common in wood and espe- cially bark are the alkaloids. Many re- cent reports cover the discovery of both new and known alkaloids, as well as structural and synthetic studies, in such species as *Annona reticulata* (253), *Aspidosperma* spp. barks (424, 641), *Alangium lamarckii* bark (70), *Ervatamia* spp. bark (24), *Entada phaseoloides* bark (404), *Elaeagnus augustifolia* bark (492), *Geissosper- mum* spp. bark (510), *Hernandia bivalis* (267), *Mitragyna* spp. (452), *Neolitsea sericea* bark (437), *Ochrosia* spp. (252), *Pseudocinchona africana* bark (162), *Phaeanthus ebracteolatus* (24), *Strychnos* spp. barks (71, 340, 410), *Teclea* spp. (472), *Voacanga* spp. barks (581), *Tabernaemontana pandacaqui* bark (189) and *Xylopia discreta* bark (535).

Alstonia spp. barks have been found to contain a variety of interesting alka- loids as well as saponins and triter- penoids (24, 141, 262). *Pouteria* spp. barks (10) and *Alchornea* spp. (471) contain the aphrodisiac, *yohimbine. Burasaia madagascariensis* wood has been found to contain a variety of alkaloids including an especially in- teresting new nitrate compound, bura- saine (515). A series of alkaloids and sterols have been isolated from *Phello- dendron* spp. barks (219, 450). Oba- cunone from *P. amurense* bark has been shown to be identical with casi- mirolid from *Casimiroa edulis* seeds (576). The commercial use of the in- secticidal alkaloid, ryanodine from *Ryania speciosa* wood, has been dis- cussed (275). *Moringa pterygosperma* contains alkaloids as well as sterols and an antibiotic (166, 346). Pelle- tierine alkaloids are the active principles in the taeniacide from *Punica grana- tum* (103) and *Duboisia myoporoides* (433) barks. The active principle has been stated to be pelletierine itself, but in the latter bark it has been shown that the compound thought to be pel- letierine is actually the ketonic isopel- letierine. The alkaloids of *Erythro- phloem* spp. barks act like cardiac poi- sons and are extremely interesting chemically. They consist of esters of amino alcohols and diterpenoid acids related to cassaic acid, which has re- cently been synthesized (608). Taxine B, the main alkaloid from *Taxus baccata* also is an ester of an amino alcohol and a diterpenoid acid (586). The distribution of HCN in *Taxus* spp. (292) and *Prunus padus* bark (358) has also been studied.

Arrow poisons and piscicides have been isolated from the barks of *Prunus capuli* (487), *Sebastiania pringlei* and *Sapium biloculare* (487) and *Juglans rupestris* and *Carya illinoensis* (487). *Casimiroa* spp. barks contain the hyp- notic glucosidic piscicide, casimirosine (487), as well as a series of alkaloids (575) including considerable amounts of casimiroin, skimmianine identical to that found in *Phebalium squamens* bark, and edulin identical to that found in *Lunasia amara* bark (500). *Lunasia* spp. barks alson contain several other similar alkaloids such as hydroxyluna- cridine and lunacridine (251, 328). The latter is the optical antipode of a desoxybalfourodine. The alkaloids, bal- fourodine, balfourolone and a methyl- balfourodinium salt are found in *Bal- fourodendron riedelianum* bark (511). Balfourolone is an artifact formed from the salt, and it is therefore sim- ilarly possible that its optical antipode, hydroxylunacridine is also an artifact, and that *Lunasia* spp. barks may con- tain a similar but antipodal quater- nary salt. Tremendous interest has been generated during the past couple of years in the steroidal alkaloids from *Holarrhena* spp. (Kurchi) bark (470). These alkaloids are excellent potential starting materials for the commercially important and potent C–18 oxygenated steroid hormones. The alkaloids themselves are also phy- siologically active and have been used in the treatment of amoebic dysentery. *Humiria balsamifera* bark is also used in the treatment of amoebic dysentery. The extractives contain large amounts of bergenin, but this is not the active component (170). This gallic acid de- rivative is fairly common, having been found in the *Saxifrage* family, *Mallo- tus japonicus* and *Corylopsis spicata* barks and *Shorea leprosula* heartwood; it is probably identical to vakerin from *Caesalpinia digyna.*

Sugar maple (*Acer saccharum*) sap has been shown to contain sucrose and an arabogalactan as the main constit- uents (4), while the leaves have been found to contain the indole alkaloid, gramine (464). This latter discovery is significant since alkaloids have not previously been found in the maple family, and this is the first time gra- mine has been reported in a tree species. An unusual amino acid, baikiain, has been isolated from *Baikiaea plurijuga* heartwood (348). *Fagara* (*Zanthoxylum*) spp. have been the source of many interesting com-

pounds ranging from alkaloids and triterpenoids to lignans, gums, piscicides, coumarins, and even insecticidal amides (24, 46, 53, 153, 160, 186, 601).

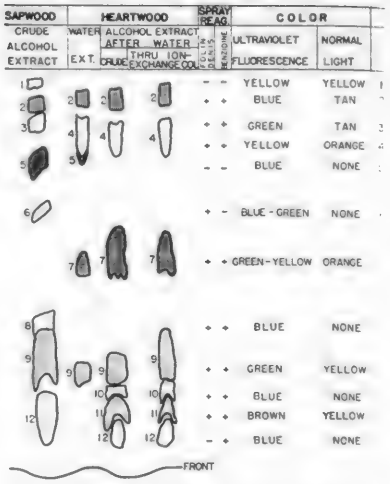
The structure of the insecticide, mammein, from many parts of *Mammea americana* has been elucidated (172). It is a phenolic coumarin disubstituted with isoprene residues. Other interesting and unusual coumarins have been isolated from the barks of *Halfordia scleroxyla* (291), *Calophyllum inophyllum* (426), *Geijera salicifolia* (379) and *Feronia elephantum* (140). Fraxidin from *Fraxinus excelsior* bark has been synthesized (8), and the effect of growth conditions on the ash and extractive content of this species has been examined (363). Alkaloids and coumarins are among the compounds isolated from *Aegle marmelos* bark (143). *Aesculus* spp. heartwood and bark have yielded a series of compounds ranging from sitosterol and triterpenoids to simple sugars and flavone and coumarin glycosides (360). The nonpolar extract of *Piscidia erythrina* bark is a fish poison and hypnotic. Among the compounds that have been isolated are rotenone, and a new compound, the closely related jamaicin (579). The bark of *Schinus polyamus* has yielded a resin active against myiasis (625). Isovitexin, which is found in *Vitex lucens* wood, has been found to be identical with saponaretin (131). Its structure is perhaps similar to vitexin but with the tetrahydrofuran ring opened. The benzene extract from the bark of *Cryptomeria japonica* has been investigated and xanthoperol isolated (285). However, xanthoperol in *Juniperus communis* wood has been shown to be an artifact (101), and that may also be true in this case.

The occurrence of β-sitosterol is so widespread that reports of its presence are only worth mentioning when no other compounds were found. Thus β-sitosterol and its β-D-glucoside have been reported in *Khaya* spp. wood (108). The medicinally active extractives of *Rhamnus* spp. barks have been extensively investigated in recent years (2, 105, 168, 197, 401, 448, 465, 648). Glycosides of phenolic anthraquinones seem to be the main active components and several synthetic and structure studies are underway. Similar compounds have also been reported in the wood. *Mansonia altissima* heartwood causes sneezing, nose-bleeding, vertigo, faintness and eczema. The active allergin has been found to be a deep red quinone (529). Also present are glycine betaine, an azulene, and also toxic strophanthidine glycosides in the wood and bark. *Acokanthea schimperi* bark contains the very poisonous steroidal glycoside, ouabagenin, which is also found in *Strophanthus gratus* (593). A saponin has also been isolated from *Anamirta cocculus* bark (24).

A couple of recent books contain much valuable information on gums and mucilages (567). Gum ghatti from *Anogeissus latifolia* has been further examined (258), and the gum from *Acacia pycantha* has been shown to be quite similar to gum arabic (54). The mucilage from *Actinidia rufa* inner bark has been studied (592). *Grewia populifolia* bark is the source of a bactericidal mucilage (530). However, no alkaloids or glucosides appear to be present. *Eucommia ulmoides* and *Euonymus japonica* bark have been found to be good commercial sources for gutta percha (249, 562). The latter has also been used as the source of a gum and cellulose pulp.

Another new α-pyrone has been isolated from *Aniba firmula* wood (260). The essential oil from this wood has been found to consist entirely of benzyl benzoate and benzyl salicylate (259). The essential oil from related species has also been investigated (258). An essential oil containing piperonylic acid has been isolated from *Ocotea pretiosa* wood (432), while a lactone-containing essential oil has been isolated from *Cryptocarya massoy* bark (577). Fungus-infected agarwood (*Aquilaria agallocha*) yields an essential oil whose main constituent is a new sesquiterpenoid alcohol, agarol (323). Alloaromadendrene has been found to be a constituent of the essential oils from *Eucalyptus globulus* and *Metrosideros scandens* (173).

Nim bark from *Melia* and *Azadirachta* spp. is a source of a number of compounds including an antibacterial essential oil and the nimbin bitters (438). The active component of the latter is nimbin whose structure has been partially elucidated; it is probably related to the furanoditerpenoids, limonin and columbin. Nimbosterol is identical to β-sitosterol. Nimbiol is similar to sugiol, but with the isopropyl side chain replaced by methyl. The sulfur-containing nimbidin has not yet been investigated. Other components isolated include sugiol, sitosterol-β-D-glucoside, a branched chain paraffin alcohol, and nimbinin. *M. azadirachta* heartwood has been shown to contain bakalactone and a terpenic acid (438). An unusual bitter principle, oleoropein, has been isolated from various parts of *Olea europaea* (556). It contains glucose, not as a glucoside, but rather as an alcohol moiety esterified with two unsaturated carboxylic acids. The nonglucosidal bitter, malanthin from *Ailanthus malabarica* bark, has been further examined



Diagrammatic reproduction of chromatogram of extracts from *Salix eriocephala* (459).

(512). A bitter principle has been isolated from *Jasminium multiforum* bark (24), and the occurrence of bitter substances in willows has been studied (564). It has also been found that *Salix* spp. heartwood with diamond cankers is very resistant. Ethanol extraction of *S. eriocephala* yielded a single phenolic compound responsible for this resistance (459). The decay resistance of *Tectona grandis* has been correlated with the amount of methanol extract after ether extraction (163).

Coprosma foetidissima bark has been thoroughly studied (109). Methyl mercaptan is responsible for the odor, and among the extractives have been found anthraquinones, rutin, quercetin, and asperuloside. Dihydroquercetin and its rhamnoside have been reported in the bark of *Quintinia serrata* (133). The main extractive of *Mundulea sericea* is mundulone, a novel isoflavone with two isoprene residues (124). *Himantandra* spp. barks have received considerable attention (82). The sterochemistry of their interesting lignans has been clarified, and alkaloids and a new sesquiterpenoid alcohol have been found. Magnolol from *Magnolia* spp. barks has been synthesized by an enzymatic dimerization of chavicol (526). Dihydromorin and dihydrokaempferol were found in *Artocarpus integrifolia, Maclura pomifera, Morus lactea,* and *M. alba,* and *Chlorophora tinctoria.* Morin itself was found only in the last species together with maclurin. Dihydroquercetin was found in three of these species. Cudranin was also found in *M. alba* wood. In addition, a crystalline phenol from *Dalbergia latifolia* wood is under study (27). The lignins extracted with methanol and the polysaccharides extracted with water have been studied in the reaction wood of

Eucalyptus goniocalyx and *Pinus radiata* (89).

Prunus spp. woods have received considerable attention. Flavanoids, including several new derivatives, have been reported in several species (154, 244, 282, 463). Both the bark and heartwood of *P. puddum* are rich in 7-methyl ethers (244). Fungus-attacked *P. jamasakura* wood contains the lignan, isoolivil, instead of some of the usual flavanoids (283). The commonly found naringenin has been shown to be a growth inhibitor (293). The phenolics in all parts of the wood and bark of *P. domestica* have also been examined (588). The methanol extracts of newly formed aspenwood have been investigated (435). *Populus tremuloides* bark has been shown to contain tremuloidin, salicin and salireposide, but no populin as previously reported (483). However, populin is present in *P. tremula* and *P. alba* barks. Aspen bark is also rich in active chlorophyll early in the growing season (486). The biochemical processes taking place in the bark of black locust (*Robinia pseudoacacia*) in relation to frost hardiness have been investigated (563). This bark is notable for its high protein content. The chemistry and pulping of *Adansonia digitata* bark has also been investigated (136). *Betula* spp. wood and bark have been examined. Recent interest has centered around the water-soluble carbohydrates (243, 389) and the bark cork (327). The gum *oleoresin* from *Boswellia serrata* has been studied (80). An examination of *Ptaeroxylon obliquum* bark showed the presence of such diverse compounds as simple sugars, tannins, a flavone glucoside, alkaloids, and a triterpenoid saponin (501). *Pterocarpus* spp., and especially the heartwood extractives, have received considerable attention in the past few years with stilbenes, isoflavanoids and related polyphenols being commonly found (78, 99, 347, 518, 550, 618). *Pyrus communis* bark has been found to contain ursolic acid (314) as well as catechins, leucoanthocyanins and arbutin, but no phloridzin (636). *Malus* spp. barks have been shown to contain tannins, phloridzin and other glycosides, but no arbutin (316, 636).

Isomeric leucodelphinidins have been isolated from *Phyllanthus emblica* bark, *Eucalyptus pilularis* kino, *Cleistanthus collinus* bark and *Myrica nagi* bark (380, 549). *Butea frondosa* kino has been found to contain cyanidin and a leucocyanidin (223). *Podocarpus* spp. heartwoods have also been examined (104, 106). A new lignan, seco-isolariciresnol, and a new isoflavone, podospicatin, have been isolated. Unusual flavanoids have also been isolated from *Melicope* spp. bark (231). Other species where unusual compounds have been found or investigated include *Dolichandrone falcata* bark (345), *Engelhardtia formosana* (600), *Ginkgo biloba* heartwood (335), *Periploca nigrescens* (413), *Swietenia macrophylla* (139), and *Simarouba amara* bark (274).

Tannins have been reported and studied in *Cotinus coggygria* (381), *Cassia* spp. barks (126, 507, 616), *Ceriops roxburghiana* bark (126, 419), *Polygonum divaricatum* (573), *Peltophorum ferrugineum* bark (616), *Rhus typhina* (584), mangrove (*Rhizophora* spp.) barks (144, 306, 485, 504, 504a, 509), and *Terminalia* spp. barks (513, 533). The tannins from *Bruguiera* spp. barks have also been investigated, especially in regard to the possibility of using them in adhesives (441). Black wattle, babul, and other *Acacia* spp. bark tannins have been analyzed (444, 457). Compounds isolated include catechin, gallocatechin, robinitenidol, anthocyanins, and leucoanthocyanins. The tannin precursors in *Schinopsis* spp. have been further studied (152). The tannins extracted from redwood by polar organic solvents have been studied, and it was shown that the extracted wood is still quite durable (13). The tannins from *Castanea* spp. wood and bark have received additional attention (416, 534). Among the compounds isolated are dihydrodigallic acid glycosides, *d*-catechin and *d*-gallocatechin. The latter two compounds have also been reported in *Casuarina equisetifolia* bark (523). A considerable amount of work has been done in recent years on oak barks. Most of this has naturally been connected with the tannins from various species, and *d*-catechin, *d*-gallocatechin and leucoanthocyanins have been often reported (20, 416). The biochemistry of these tannins has been discussed by Hathway (286). *Quercus suber* bark has been mentioned as a raw material for the perfume industry (531), and Hergert (294) has carried out further research on the cork. Quercitrin from the inner bark of North American black oak has been briefly mentioned (268).

A large amount of work has been carried out on *Eucalyptus* spp. woods. Aside from a number of general papers (89, 164, 555), the condensed tannins have been examined (308), and the polyphenols and shikimic acid in the wood and cambium have been investigated (309). A trihydroxystilbene and its glucoside have been isolated from *E. wandoo* heartwood (287). The Australians (31, 307) have examined the tissues of different species and kinos (240). Problems encountered in the handling of black liquor from the pulping of eucalypts were shown to be associated with the presence of ellagic acid and its derivatives. To assist the assessment of commercial polyphenols as a basis for wood adhesives, the reaction under different conditions between a model compound, catechin, and formaldehyde was studied. Reactivity with formaldehyde was greatest at pH 8 and was confined to the phloroglucinol ring of catechin. Anthocyanins in eucalypt bark have been studied (305, 380) and a satisfactory tannin has also been prepared (20, 182, 362). In addition, the Australians have investigated the anatomy of *Eugenia* spp. barks (31). From *Pithecellobium dulce* bark has been isolated a 25 per cent yield of a good catechol-type tannin, while from *P. saman* bark has been isolated the novel compound, pithecolobine, which contains four nitrogens in a nineteen-membered ring (617).

Other species on which chemical investigations have been carried out include *Araucaria* spp. (310), *Crataeva religiosa* bark (77), *Cinnamomum* spp. bark (111), *Cinchona* spp. barks (393), *Vitis vinifera* wood (303), *Carya* spp. (425), *Dysoxylum spectabile* heartwood and bark (132), *Eucalyptus rostrata* (384), *Helicteres isora* bark (58), *Jatropha glandulifera* bark (559), *Randia* spp. (261), and *Tabernaemontana* spp. barks (586).

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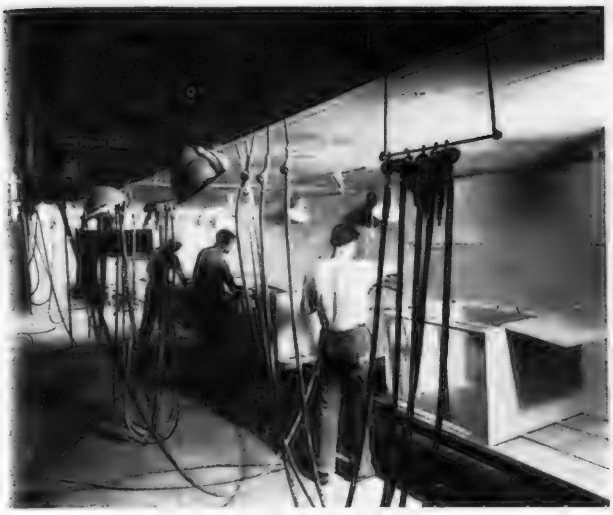


Conveyorized finishing systems.

Conveyor Systems Inc. installations in a furniture plant.

1959 SUMMARY OF

Wood Finishing Developments

D. G. Lubeck[1]
Chairman, FPRS Wood Finishing Division

Highlights of '59 progress on exterior and interior finishes, foreign developments, and education are presented. For 1960, a concentrated effort on fundamental aspects.

The Wood Finishing Division has completed a very ambitious and successful program for 1959. The highlights of the year's activities were the programs presented at the Forest Products Research Society's National Convention in San Francisco, and the North–Central Regional Program in Chicago.

San Francisco Program

The program in San Francisco consisted of two sessions. The first session covered the latest developments in finishing materials, and the second session the latest developments in processing techniques. The subjects covered were as follows:

Morning Session: Fire-Retardant Latex Intumescent Coatings; Alcohol & Solvent Resistant Furniture Finishes; Polyurethane Wood Finishes. New Finishes for Wood; Development in Color Finishing for Plywood—Precolor Sealing System & Rollgrain Printing; Acrylic Finishes for Exterior Wood Surfaces; Epoxy Resins for Wood Finishing.

Afternoon Session: Controlled Temperature—Low Pressure Spray; Airless Spray; Steam Spray; Hydro-Spray; Automatic Spraying Techniques; Catalyst Spraying Techniques; Pressure Curtain Coaters; Electrostatic Spraying; Rollcoating; Flowcoating and Dipping; Infra-Red Drying, Sanding Techniques:

The Author: Don Lubeck holds a BS in wood technology from the University of Michigan. He works with finishing systems for the Hammond Organ Co.

North-Central Regional Program

Because of the popularity and timeliness of the San Francisco Program, the North–Central Region of the Forest Products Research Society requested the Wood Finishing Division to present a similar program in Chicago. The Program in Chicago covered two full days. The subjects covered were as follows:

First Day: Airless Spraying; Roller Coating; Pressure Curtain Coating; Automatic Spraying; New Finishing Materials; Conveyor Systems; Flowcoating and Dipping; Catalyst Spraying and Controlled Low-Temperature Spraying; Infra-Red Drying, Pumping Systems and Hydro-Spray process;

Second Day: Abrasive Grits, Backings, and Uses; Sanding in the Plant Layout; New Applications and Developments; Discussion of All Finishing Problems.

Division Officers

Mr. Clark Hatcher of the Drexel Furniture Company, has been elected Vice-Chairman of the Wood Finishing Division. Mr. Hatcher will take over the duties formerly handled by Mr. Donald Laughnan.

The present officers of the Wood Finishing Division are as follows: Chairman—Mr. Donald G. Lubeck, Hammond Organ Co., 2915 N. Western Ave., Chicago 18, Illinois; Vice-Chairman—Mr. Clark Hatcher—Drexel Furniture Co.—Drexel, North Carolina; Education—Mr. John D. Sullivan, Asst.–Prof., Wood Technology, School of Forestry, Duke, University, Durham, North Carolina; Fininshing Materials — Interior — Mr. F. H. Thomas, Sherwin–Williams Co., 11541 S. Champlain Ave., Chicago 28, Illinois; Finishing Materials—Exterior —Mr. Neil B. Garlock, National Paint, Varnish and Lacquer Assn., 1500 Rhode Island Ave., N.W., Washington 5, D. C.; Foreign Developments—Mr. M. J. Merrick, Head Research Department, The Furniture Development Council, 2–4 Dalmeny

[1] Contributors to this review are: *Interior Finishes*—J. H. Whiteside and F. H. Thomas. *Exterior Finishes*—Neil Garlock, A. E. Gruhl, R. F. Buller, E. E. Callis, W. P. Fuller, W. A. Dost, R. H. Lalk, L. P. Larson, C. F. Koda, D. F. Laughnan, R. S. Taub, and Paul Whitford. *Foreign Developments*—M. J. Merrick. *Education*—J. D. Sullivan and J. H. Whiteside.

Ave., London, England: Processing Equipment and Techniques—Open.

Montreal Meeting

The Wood Finishing Division's Program for the 1960 National Convention to be held in Montreal is titled, "Problems and Progress With Wood Finishes". Clark Hatcher has prepared a very impressive program with the following distinguished speakers: Mr. W. C. Finley, Battelle Memorial Institute, Columbus, Ohio; Mr. Joseph Hager, Vice President, Grand Rapids Varnish Corporation, Grand Rapids, Michigan; Mr. G. Maurice Hill, Vice President, Drexel Furniture Company, Drexel, N. C.; Mr. Leon Offman, Manager, Art Shop, Toronto, Canada.

Past programs presented by the Wood Finishing Division have dealt with new finishing materials, various test methods, and the latest in processing equipment. It is the intention of this Division to continue along this line. However, in addition, more effort will be directed towards more fundamental aspects of wood finishing. We shall endeavor to satisfy those individuals who demand technical programs and those who need the more practical approach.

It generally takes an Annual Review for one to realize the reason why more of the presently available advanced technical equipment and finishing materials are not being adopted. The reason, to a great extent, lies with the fact that the requirements and responsibilities of wood finishing are not understood.

The present method of operation is to start the product out and push until it gets through. This process is normal and generally works out quite well. Through the trial and error method, various safeguards are added to the process. Examples would be an extra coat, double filling, additional dry time, etc.

Under the present-day process, rarely are problems involved with wood finishing solved by correcting the trouble at the *source*. They are corrected by variations in the processing techniques.

When new finishing material, or processing equipment is incorporated, it is done under careful observation. When these processes and materials are incorporated to replace existing processes, they require their own set of safeguards. This generally puts anything that is new in a bad light. The reason for this is new materials and equipment emphasize poor processing practices. They do not have the safeguards or flexibility of the materials or processes they replace. An example of this can be found in attempts to substitute synthetics for lacquers.

It is surprising to learn how few people in the business of finishing wood, recognize the problems and understand the requirements for proper wood finishing. To be able to recognize the difference between cold checking and grain checking, of shrinkage and open grain, the factors of adhesion, of trapped air and trapped solvent, is mandatory. One cannot argue that wood finishers are successful. The present volume of finished woodwork is tremendous. The point made here is that under the pressure of time and cost, modern wood finishing must become a science. To this end, the Wood Finishing Division will concentrate its efforts in 1960.

Education

Interest in research and development in the wood finishing field is not confined solely to private industry. Various colleges, technical schools, and universities throughout the world have made significant contributions to the surface coating enterprises. More particularly, here in the United States, these contributions fall into three general categories: (1) students, (2) product development, and (3) basic research.

The matter of students is of primary importance to the wood finishing industry. Seven major universities and colleges offer courses that deal directly with wood finishes and finishing. These schools are Alabama Polytechnic Institute, Duke University, University of Michigan, Michigan State University, University of Minnesota, State University of New York (College of Forestry) and North Carolina State College. For the most part, these institutions are geographically located near important furniture manufacturing areas and the local interest in wood finishing justifies some academic concentration on this phase of wood technology. These schools generally are well equipped with conventional air-spraying equipment and, owing to the generosity of industry, are well supplied with a wide range of materials. The results is a student well trained in the fundamental theory and practices involved in the application of surface coatings to wood.

In addition to the seven schools mentioned above, there are about fifteen colleges and universities in which wood finishing is included as a portion of more general courses in forestry, forest products and wood technology. Many of these institutions also teach wood finishing to small groups of interested students as a special problem.

Desirable training in the basic theory of surface coatings is also available in the chemistry departments of a number of schools. Foremost among these are Western Reserve University, North Dakota State College, (Fargo), Georgia Institute of Technology, University of Missouri (School of Mines and Metallurgy, Rolla), Case Institute of Technology, High Point College and Florida State University. The emphasis has been largely in coatings for metals and wood. However, these subjects have not been considered seriously in the teaching program at these schools. Almost every chemistry department in American colleges offers several courses of basic interest to the wood technologist. The chemical fundamentals of adhesion are well covered in such courses as advanced organic chemistry, colloid chemistry and polymer chemistry. Unfortunately, it is only the exceptional wood technology student who has the chemistry courses normally considered prerequisite to these more advanced courses. On the graduate level, however, there are many more qualified students available and need only to be guided into these fruitful areas of endeavor.

The academic institution has largely been ignored by industry with respect to product development. Fortunately there are a sufficient number of exceptions to the preceeding statement to point out an encouraging trend toward more cooperation between school and industry in this important segment of the finishing field. For example, the University of Michigan in cooperation with an abrasives manufacturer has completed some very interesting wood machining research. None can deny the importance of machining and surface preparation in the finishing of wood. More recently, Duke University has instituted a development program in association with one of the leading producers of airless spray equipment. There is no doubt that other leading universities and colleges also anticipate or are actively engaged in similar projects. The importance of this type of association is obvious and it appears to be only a matter of time until it is considered generally desirable by industry.

The professional societies and trade associations have shown considerable interest in the product development potential of the academic institution. In some cases, this interest has assumed the form of scholarships and research programs that are certain to benefit industry as a whole. The results of such programs should be considered apart from the promotional aspects that can so easily ob-

sure the real merit of these cooperative enterprises.

Next to the contribution of students, the potential of the academic institution for basic research in wood finishing is most important to the industry. Faculty members and doctoral degree candidates in Wood Technology comprise a pool of talent, knowledge and interest that can and should be exploited through the medium of fundamental research. There is no other place for the wood finishing industry to find the peculiar combination of botany, engineering, and chemistry necessary for the exploration of the real variables to be encountered in wood research. Over the years the trial and error method has proved exorbitantly costly to the wood industry, and it is a credit to that same industry that it has progressed so far on such limited information. The academician can help to supply industry with useful primary facts, but he cannot do it alone; he needs at least the encouragement of industry. Fortunately, the more progressive segments of the wood finishing business do recognize the necessity for basic research and this recognition is a vital means of encouragement in itself. Financial aid toward the fundamental approach is essential and has been steadily increasing in recent years. Basic research projects at such schools as the University of California, Michigan State University, Yale, Duke, and Syracuse bear witness to the support of industry.

Finishing Materials—Exterior

Perhaps the most radical departure from old practices was the offering for sale of exterior emulsion paints for wood. These have been experimental for several years, and enough background has been built up that several companies are promoting them widely. They are recommended for use over oil primers or special primers, although at least one company is working on an all-emulsion system for new wood. The emulsion paints have the same ease of application and rapid dry that have been the case with interior emulsions. Research results were published which dealt with the causes for fading or change of color of exterior emulsion paints. Considerable work was done to improve the adhesion of emulsion paints to chalky surfaces. One suggestion is the addition of a small quantity of boiled linseed oil to the emulsion paint. The oil is claimed to bond the chalk and form a good base for the paint. New results for emulsion paints are continually being developed. They will appear in paints on dealers' shelves in a year or two. The effort to improve the shortcomings of emulsion paints goes on continually.

Latex emulsions which are compatible with zinc oxide have been announced, and the use of zinc oxide in emulsion paints is being considered. Zinc oxide helps resist mold.

New clear finishes for the natural finishing of siding are being marketed. They are claimed to have greater life and better repaint properties than older finishes. On the other hand, one lumber association has recommended that no finish be applied. A waterproofing solution is recommended, since this restricts the darkening and growth of mildew on the wood. The use of a water-repellent solution under paint is becoming better known as a device to lengthen life of a paint film. The reasons for its value were described.

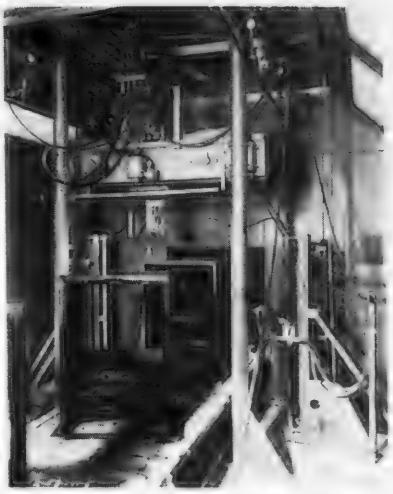
The use of alkyd vehicles for house paint is becoming wider spread in some localities. It is said they have largely supplanted linseed oil paints in some areas. The alkyds used in most cases are iso-phthalic alkyds. These provide better drying properties than linseed oil, and they are superior to the resins used for interior paints.

The value of phthalic alkyds in retaining loss and color in trim paints was described in a paper. Various new formulation components were considered.

Some lumber companies have begun marketing pre-primed siding lumber, and they are considering two-coat factory finishes. This is a measure to meet competition of materials that are not painted.

The Product Research Department of the Douglas Fir Plywood Association is presently studying all types of finishes and coatings which can be applied to plywood. Included are plastic films and liquid materials such as polyesters, urethanes, epoxies and synthetic elastomers. High solid formulations of these plastic coatings can satisfactorily hide the surface defects of low grade veneers and control or mask out face-checking. Inert surfacing materials can be added to present a very attractive textured surface and further conceal flaws in the substrate. Coatings for plywood for both interior and exterior use in varied textures, brilliant colors and excellent durability are possible in the near future.

Economical asphalt-asbestos and aluminum asphalt coatings are being examined as roof coatings applied directly to plywood. Asphalt cement is applied first to the joints between panels, fiber glass tape embedded in it to seal the joints, and then the entire plywood roof cold-sprayed or brush-coated with the asphalt roof coating. Aluminum or white top coats make attractive roofs, but will yet have to be time-tested for durability.



Automatic spray equipment by Binks Mfg. Co.

Cold Airless Atomization equipment by Gray Co. Inc.

The problem of sealing the joints between plywood panels is of extreme importance and is necessary either before or after the application of any coating to the panels.

Numerous joint sealants are under extensive lab and field tests to find a durable and economical seal for the joints between plywood panels. Thiokols, synthetic rubber compounds, have proved most durable. Simpler, one-component, Hypalon caulking compounds are currently under test.

Foreign Developments in Wood Finishing

The year has been one of consolidation and development in the field of wood finishing, rather than one in which new materials or methods have appeared. This was to be expected, since the large variety of different wood finishing materials in clear and pigmented forms which have appeared on the market in recent years have made a form of sorting-out process in

evitable. So far as wood finishes are concerned, the main interest is concentrated on polyesters; both the unsaturated type crosslinked with styrene, and the isocyanate crosslinked variety. The former have found very wide application in the finishing of radio and television cabinets. In parts of Europe they have largely displaced nitrocellulose finishes. The very high gloss does not seem to be so popular with the buying public in the United Kingdom and this, coupled with the fact that the process is complicated for the small manufacturer, has meant that the proportion of cabinets finished in polyester in Britain is rather lower than it might otherwise have been.

In the furniture field, the use of polyesters is not so widespread. The reasons for this are due partly to aesthetic considerations, partly owing to the need for careful control in production, and partly to the difficulty of finishing any surfaces that are not flat or at least simple in profile. Some of the production drawbacks of polyesters have been overcome by the introduction of the reaction coat method whereby catalyst mixed with nitrocellulose is first applied to the article, either by spreading or curtain coating, and the resin is applied in a separate operation. This advance has overcome a number of the difficulties associated with the short pot life of the polyesters, and has given rise to further opportunities for using them.

An interesting process used in France to apply polyesters is a mixture of spraying and press operation. The liquid resin is sprayed on a stainless steel platen to the desired thickness and the film is then pressed on to the sheet material to be coated. This gives a quick and economical way of finishing flat panels, and is said to be a serious competitor to the melamine films which are more commonly used in this type of operation.

While on the subject of melamine it might be worth mentioning that wood veneers and wood finishes generally have felt some competition from melamine coated paper laminates in fields in which they were hitherto supreme. The use of melamine coated laminates as decoration on wardrobes, sideboards, etc., has been a feature of some contemporary furniture designs. Melamine impregnated wood veneers are also being used. Whether this, however, is a significant change or whether it is purely a passing fashion is difficult to say.

Another interesting development is the use of a cold catalyzed melamine based lacquer for bedroom and other furniture. It is understood that the spraying process may be carried out with no more difficulty than in using nitrocellulose, and is said to combine the advantages of melamine with the ease of nitrocellulose. The formulation, in fact, the whole process is rather a trade secret, however, so it is difficult to find facts.

On the equipment side, the use of curtain coaters has spread widely, both for cellulose and conventional finishes and also in the application of polyester materials. Modifications and refinements in the designs of these machines have been made and some of the earlier snags overcome.

Use of electrostatic spraying has spread a little, and one large British chair factory has installed a complete plant. In this connection it should be pointed out that the normal moisture content of timber used for chair making in the United Kingdom, about 12 percent, is sufficiently high to give the wood sufficient electrical conductivity to enable electrostatic spraying to be used without the use of special conductive coatings, etc.

Another interesting development from Germany is the installation of an electrostatic spraying plant for finishing radio cabinets in polyester material. This is quite a big step forward since the waste in normal spraying, and most radio cabinets are sprayed, becomes much more serious with polyester in view of the high cost of the material compared with nitrocellulose.

As far as exterior coatings are concerned, the search has continued for a clear varnish which will withstand more than one or two years service in the British climate. The Timber Development Association in particular has been carrying out a series of field trials and results were made known during the year. It appears that the phenolic-tung oil or the phenolic modified alkyd-tung oil varnishes behave the best. The newer polyurethane materials have also proved rather promising although their difficulties in application will not make them popular with the normal exterior decorator. The behavior of epoxy based materials was disappointing. In spite of this, however, even three coats of the best material used in the test program could not be guaranteed to last outside for more than two years. This is a very serious matter in view of the increasing popularity and use of wood and wood products as exterior cladding material.

Finishing Materials—Interior

The year 1959 saw final barriers broken in important development work that now makes possible the formulation of sensationally new finishes for furniture and other interior wood surfaces for what is being predicted will be "the fabulous 60's".

Methods of applications were perfected for applying the new polyester and epoxy finishes that show promise of replacing printed wood grain furniture and plastics with genuine wood and sprayed-on finishes. The solution of the adhesive problem with aluminum foil—plywood construction provides the burn resistance required for these surfaces and a nationally known testing laboratory pronounces this construction and finish equal to or better than the plastic imitation finishes.

In addition to the new finishes mentioned above, other noteworthy developments and improvements were as follows:

Pigment Toners: There was more use of transparent pigment toners for the low solids, high shrinkage type for sap staining and for part of the undertone color. They are frequently used in connection with NGR stains, but in separate application.

Emulsion Coaters: These materials, under study for 3 or 4 years, have proved of value as washcoats and as sanding coaters over filler. They help with pinhole prevention and in some systems produce remarkable toughness. Lacquer topcoats are generally used over them.

Catalyzed or Conversion Lacquers: This relatively new product has qualities about equal to alkyd-urea synthetics. They are faster in drying and better in rubbing. They give better intercoat adhesion properties and respond better to normal patching procedures. They cost more per unit of solids but are proving popular in the field.

Ultra-Violet Screening Agents in Topcoats: These materials are growing in volume use. They have definite value in prevention of yellowing of bleached woods and white woods. They subdue fading of some dyes. They appear to have no important value over unbleached colored dyes.

Airless Spray: At least two furniture manufacturers in the medium volume range have now gone into full use of airless spray—one for all materials, including stains; the other for topcoat lacquers only. Several other furniture manufacturers seem to be considering this method quite seriously.

Vinyl Plastic Problems: The subject of vinyl plastic resistant coatings or vinyl barrier coatings seems to have become pressing again this year after being quiet for several years. Some fabrics show extreme softening action against orthodox lacquer finishes. The preferred recommendation for this problem is to use catalyzed conversio

rnishes either as the complete finish r as topcoat only over an orthodox nish. Thus, in some cases, chair ames brought up in standard lacquer ishes are recoated on the chair seat ea only when pieces are to go into vinyl covered fabric.

Rubber Staining of Lacquer: A cquer has been developed that is re-stant to the staining normally ob-ined by lamp cords which have been otected with synthetic rubbed com-unds. It uses Paneplex G–40 resin d nitrocellulose.

Multi-color Lacquer Enamels: hese materials are still finding new ses as a decorative interior coating r walls, furniture, TV cabinets, etc.

Infra-Red Drying: Infra-red dry-ng of finishes on wood has been de-veloped to the point that several man-ufacturers are now using it in produc-tion. One manufacturer states that it has cut his finishing time from ap-proximately 9-1/2 hours with convec-tion heat plus overnight air dry, to approximately 2 hours and 40 minutes.

Door Finishes: One manufacturer is reported to be prefinishing doors with an acrylonitrile-styrene-alkyd co-polymer resin which dries with the speed of lacquer—tack free in 5 to 10 minutes.

Bleaching: There are two recent developments of note. First, the so-called A.B.C. Peroxide Bleach. After the conventional caustic peroxide bleaching process, the wood is usually neutralized with vinegar or acetic acid and sponged off before final drying. Otherwise, a caustic residue may be left in the wood and poor adhesion may result. The A.B.C. Bleach em-ploys a volatile activator instead of caustic. This evaporates completely and no residue is left to be sponged off. Thus, by elimination of the neu-tralizing, sponging and extra drying, several hours to possibly a full day may be saved in the preparation of furniture for finishing.

The A.B.C. and the regular bleach are of the peroxide type, and a fire hazard exists if they are applied in the same booth as other finishing mate-rials; and usually a separate booth for bleaching is considered necessary for safety.

Numerous attempts have been made to simulate bleaching by the use of pigmented toners. Such finishes, un-fortunately, rarely exhibit the clarity of a peroxide bleached finish.

A new system, free from fire haz-rd, provides a bleached effect ap-proaching a peroxide bleach in clar-ity. This system consists of two steps: (A) a first coat which is sprayed brushed or ragged on, and dried at least half an hour at room tempera-ture, and (B) a second coat which is sprayed on and dried at least half an hour at room temperature, From this point on, conventional materials such as wash coat, filler, sealer, and lacquer may be used to complete the finish. This system is satisfactory over mahogany, cherry, and walnut, but should not be used on oak. This two-step system will not replace a peroxide system where a very light finish is re-quired or where the variation in wood colors is too great. It has proved quite satisfactory where a slight to moderate bleached effect is desired.

In the past, furniture stains have not been as lightfast as either the fin-ish manufacturers or the furniture makers have desired. The reason for this has been that better dyestuffs suit-able for stain manufacture simply were not obtainable. About two years ago, however, stains of much improved re-sistance to color change became avail-able. As is the case with so many good things, the newer type stains cost more money. In some of the weaker shades the cost difference is marginal while the stronger shades command a sub-stantial premium.

While vinyl sealers have been avail-able for a number of years, they have not been used as widely as they might. Vinyl sealers can contribute extra toughness and adhesion to a finish-ing system. Perhaps they have not been as popular as they might have been because they have been difficult to sand. However, vinyl sealers with much improved sandability have re-cently become available. Also, the use of the new stearated sandpapers make the job of sanding these sealers much easier. Usually the vinyl sealers are used in addition to conventional lac-quer sealers, but in some cases will replace them.

Woods change color on exposure to light. In fact, the change in the color of the wood is usually much greater than any change in the finish which may cover its surface, particularly if the finish is water white. Most of the color change in wood is caused by the ultraviolet portion of the light. In the last few years chemicals have become available which will absorb or screen out the ultraviolet portion of light, and when certain of these are incor-porated in a finish they protect the sur-face of some woods from discoloration. They are most effective over maple, bleached mahogany, and oak; and are of less value over other woods, such as walnut, or over toners.

Many finish manufacturers will add a screening agent to the finish if re-quested. Inclusion of the agent usually raises the cost up to 25–30 cents a gallon. The user must balance the added cost against the color stability of his furniture.

Heat-Reactive Varnishes: Heat-reactive varnishes as such are no longer new, but they have been im-proved to such an extent over the last few years that they should be included in this discussion.

Their solids content is higher than lacquers. Whereas total solids of the latter run from about 21 to 24 percent for cold spray and to about 30 percent for hot spray, heat-reactive varnishes run from about 35 to 42 percent, the usual range being about 37 to 40 per-cent. Normally a catalyst is added just before use. Cure time is ordinarily about 2 hours at 140° F. or overnight at room temperature. The fully cured coatings are more resistant than lac-quers to alcohol, nail polish, cigarette burns, etc., and are less affected by the pitches and oils naturally present in some woods. Certain grades are more resistant to staining by rubber articles. Print resistance is usually better. Some grades are used for finishing the "Beauty Guard" construction of the fine hardwoods association. Cold-check resistance, color retention, adhesion, etc. are similar to lacquers. On the solids basis the heat-reactive varnishes are often more economical. In the past, the odor of heat-reactive varnishes has often been objectionable in the finish-ing room unless ventilation has been very good. However, certain grades have recently become available which have little more odor during applica-tion than lacquers. The usual type of heat-reactive varnish has not dried to be dust-free as rapidly as lacquers. Here again, some of the newer types approach lacquers in setting time. Heat-reactive varnishes are not as fool-proof as lacquers and are more diffi-cult to repair.

Acetate-Butyrate Lacquers: These lacquers are attracting increasing at-tention by furniture makers. One of the first applications of butyrate lac-quers was in a finish which would be resistant to staining by rubber lamp cords, typewriter feet, etc., as rubber may cause bad discoloration of even the best water-white nitrocellulose lac-quers. The first such lacquers required very special precautions to avoid adhe-sion difficulties. However, modifica-tions in the last few years enable the user to apply them much as he would a regular lacquer. While they have been valued for their resistance to staining by rubber, probably most of the recent interest in butyrate lacquers has been due to their resistance to softening and marring by plastic up-holstery and to their excellent resist-ance to discoloration by ultraviolet light. They are of particular value on

blond furniture for this latter reason. They are more resistant than lacquers to discoloration by urethane foams. They are somewhat harder to rub than regular lacquers, but they polish to a high gloss. Adhesion, toughness, cold check resistance, etc. are comparable to good nitrocellulose lacquers. Their cost is somewhat higher at the present time.

Polyurethane or Isocyanate Finishes: These finishes usually consist of two parts which are either mixed together just before use or are sprayed through a two-headed gun. The sprays mix in the air, or preferably, mix in the nozzle of a special gun. They can form a very tough finish with high adhesion and very high resistance to abrasion, and to a variety of chemicals. Polyurethane finishes may be sprayed up to about 80 percent solids.

Generally they tend to be slow in drying; they are hard to rub; color retention is relatively poor; and they have a tendency to bubble in the presence of moisture or high humidity, either in the film or in the container. They may cause dermatitis. Also, their vapors may be somewhat toxic, though the cured film is not. For a number of them, special spraying equipment is needed. Considerable improvements have been made recently in polyurethanes and they appear to have a place on furniture for certain specialized purposes. They are still quite expensive. They are being used at present mainly for chemical resistant finishes in chemical plants and oil refineries and in places where their outstanding abrasion resistance is important.

High-Solids Epoxy Finishes: These finishes may be applied at solids approaching 100 percent. Their use in the past has been mainly for chemical resistant and abrasion resistant applications on metal and concrete. They are usually two-part or catalyzed finishes and special equipment is required to spray them. In the past their color retention has not been as good as might be desired for furniture work. There have been problems of flowout and of toxicity due to the catalysts employed. They do not rub nearly as well as lacquers. Improvements are being made and it seems possible that at least some of these deficiencies may be overcome. The cost of epoxy finishes has been too high for most furniture work, though some reductions in cost are in sight.

Polyester Coatings: Polyester coatings have interested furniture manufacturers more than polyurethanes or epoxies and appear to be of more immediate application in production. While the term "polyester" may apply to a variety of materials, from dacron yarn to a soft, molasses-like plasticizer, the use here denotes a finish with high film-former content, based on an unsaturated alkyd resin, which is cured with a special peroxide type catalyst. Numerous problems attended the first attempts to make polyester finishes. They cratered badly; adhesion was poor; they sagged badly on vertical surfaces; color retention was not good; and oxygen in the air inhibited their cure. While these problems have in the main been solved, polyesters have not quite reached the stage where they may be used generally for case goods. At present they lend themselves better to flat work finishing of knock-down furniture, wall panelling and flooring. Polyester finishes on particle board show better levelling and less shrinkage than conventional finishes.

There are two rather general types of polyester finishes, the so-called wax type which dries to a dull finish, and the wax-free type which dries to a gloss finish.

First of all, the wax type. This type will not dry properly unless air can be excluded from the surface, so a small amount of wax is incorporated. The wax crystallizes on the surface and protects the coating from air during the cure. The film-former content is 88 percent as applied. Actually about 80 percent of the finish which reaches the surface remains after curing. We have experimented with the pressure curtain type of application but we have devoted most of our efforts to spray application. A special catalyst gun is required such as the Devilbiss J.G.C. 501 Gun. Polyester and catalyst are placed in separate pots and the flow rate of each to the gun is controlled by fluid pressures on the individual pots. The fluid pressure on the polyester pot is raised until the desired flow rate is obtained; then the catalyst flow is adjusted to be 10 percent of the polyester flow rate. The catalyst is atomized within the head of the gun and the catalyst-laden air is then used to break up the polyester stream as it leaves the nozzle. Thus the catalyst does not mix with polyester until it leaves the gun.

The wax type polyester gels in about 15–30 minutes at room temperature (77° F.). It cures overnight at room temperature, or after 45 minutes at 95–100° F., followed by 1-¼ hours at 140°F. (Total 2 hours). While the cured film is dull, it may be rubbed readily to a brilliant gloss. It may also be wooled and waxed or finished with pumice. Rough sanding may be done with 240 through 320 dry paper.

The polyester does not clog the paper. While the wax type polyester as applied is somewhat dark, it bleaches considerably on curing. Color and color retention are on the order of a light amber lacquer. It may be applied heavy or thin, and a heavy film cures about as fast as a thin one. One ordinary coat will lay down about as much film as four coats of a 21 percent solids lacquer and a 10 millimeter dry film is easily obtained. The cured film is highly print resistant and abrasion resistant. It is resistant to alcohol, naphtha, fingernail polish, orange, lemon, and tomato juice, water and butter, and has very good resistance to discoloration by rubber. Cold-check resistance is excellent. It works best over mahogany, walnut, cherry and maple. It works well over oak veneer, but not so well over edge-glued oak flooring and with exposed edge grain. It does not work so well over pitchy or oily woods such as fir or pine, and occasional wet spots are encountered on birch, though it appears that a special sealer may take care of some of the problems on these woods.

A typical system is:

1. N.G.R. stain
2. Special clear primer (on mahogany and walnut)
3. Sealer for polyester
4. Polyester filler (over open pore woods)
5. One coat polyester

The wax-free type of polyester is a somewhat newer development. In general, it behaves like the wax type and has similar properties, except for the following notable differences:

The wax type film cannot immediately be cured at temperatures over 105° F., while the wax-free type film may be cured in as little as 10 minutes at 120–140° F. immediately after application. No flash-off time is needed. Color retention of the wax-free type is superior to that of the wax type and is actually better than that of a good water-white lacquer. Adhesion of the wax-free type is better than the wax type. It is less sensitive to inhibition of cure by the more difficult woods. While the theoretical film-former content of the wax-free type is close to 100 percent, we find that about 70 percent of the coating applied remains in the cured film. It sands somewhat harder than the wax type and is best sanded with stearated sandpapers.

Because of the high film thickness retained, only one coast suffices for most purposes, and a substantial saving in labor and equipment may be effected. The wax-free type is more expensive than the wax type, yet the cost per pound of film solids is comparable to that of a water-white lacquer.

TRENDS AND TROUBLES....

Veneer and Plywood, 1959

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Hardwood plywood troubled by imports. Progressive plants meet competition by more automation, prefinishing, and new products. Softwood plywoods boom ahead while improved equipment and techniques hold down costs.

THIS REPORT REVIEWS some recent developments in the veneer and plywood field. The report is divided into three parts: The hardwood plywood industry, the softwood plywood industry, and recent literature.

Hardwood Plywood

Hardwood plywood is being hard pushed by foreign imports. According to a report in the April 27, 1959, issue of U.S. News and World Report, 20 hardwood plywood companies have gone out of business in the past 6 years. The primary cause of this loss is said to be lower labor costs in countries such as Japan, which can then undersell hardwood plywood produced in the United States. The article suggests two approaches: More automation in U.S. plants using fewer people or move production from the United States to some of the countries having low labor costs. The U.S. industry, led by the Hardwood Plywood Institute, is seeking relief of this situation by asking for quotas on imports of hardwood plywood. To date, the U.S. Congress has not seen fit to act on this request. In contrast, the Canadian Government, at the insistence of eastern Canadian plywood manufacturers, has restricted imports of Philippine mahogany plywood made in Japan.

Some of the more progressive hardwood plants are meeting this competition by more automation in their plants and by development of new products. G. W. Smith describes automation at one progressive hardwood plywood plant in Paper No. 57, WBI-2, delivered at the American Society of Mechanical Engineers in 1957. Another progressive U.S. plywood company recently announced a planned expansion and modernization for 1959 to cost about 11 million dollars.

Fig. 1.—Laying press-dried tanoak veneer flooring in mastic on a concrete subfloor.

One of the trends in hardwood plywood is toward more complete manufacture at the plywood plant. This is most striking in the use of prefinished plywood paneling. Many of the larger hardwood plywood plants have finishing lines, and most of these finishing lines are highly mechanized. Some of the plants also supply trim to go with their paneling. Prefinishing is standard technique for most plants making hardwood plywood flooring blocks.

A new development in the flooring field is the use of veneer in a single sheet as flooring. A report describing laboratory work in this field was published in the Forest Products Journal in September 1952. Since then, three companies have developed modified processes and are now offering partially stabilized veneer floors. A fourth company is in the process of developing a very thin veneer floor.

A new foil-backed veneer sheet has joined other commercially produced special flexible paper and fabric-back veneers. These products are reportedly suitable for applying directly to plaster, wallboard, plywood, and other smooth surfaces using special adhesives.

Softwood Plywood

The softwood plywood industry has continued to boom ahead in the past 2 years. The Stanford Research Institute's report on America's Demand for Wood 1929–1975 predicted in 1954 that the total production of softwood plywood would be about 7.2 billion square feet (3/8 inch equivalent) by 1975. This goal may well be exceeded in 1959, with a predicted further increase to about 8 billion square feet in 1960. This has been accomplished by opening new plants and modernizing many of the old ones. Automatic lathe chargers, retractable chucks, air jets replacing tipple men, mechanical veneer dryer feeders, electronic moisture detectors, more efficient and economical patchers, automated jointing and edge gluing, mechanical pressloaders and unloaders, automatic trim saws, and automatic feeding of panels to improved wide-belt sanders—these are

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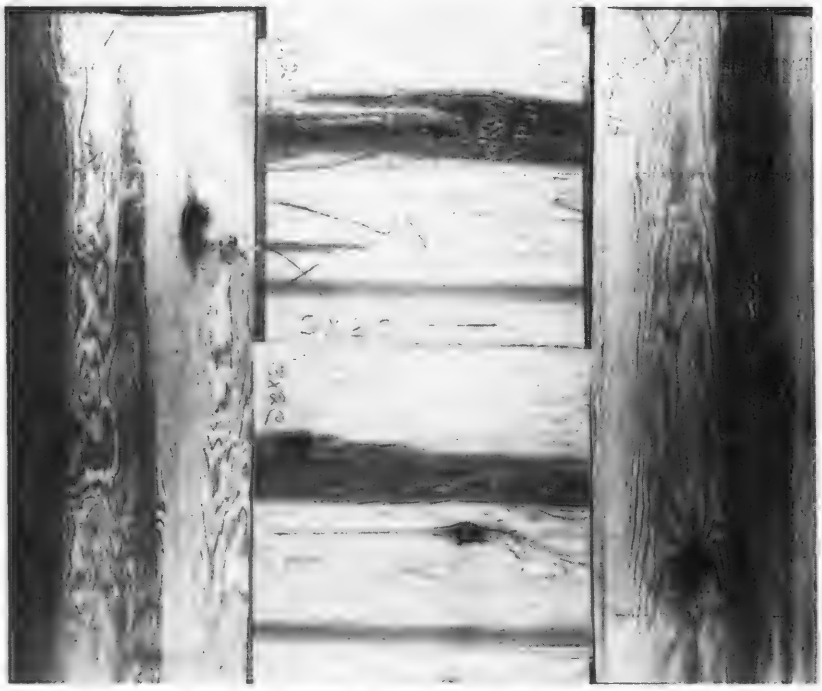

Fig. 2.—Douglas-fir veneer containing a limited amount of white pocket and knots. This grade of veneer is now permitted in standard panels of Douglas-fir plywood.

some of the mechanical developments that are helping to hold down costs while the industry is using continually lower grade peelers.

The press for suitable raw material has also resulted in the use of alternate species as well as more low-grade logs. Last year the commercial standard for Douglas-fir CS45–55 was modified to admit the use of Douglas-fir containing limited amounts of white pocket. This change was made only after extensive gluing and mechanical tests were made at the U.S. Forest Products Laboratory in cooperation with the Douglas Fir Plywood Association. These tests showed that white pocket can be glued satisfactorily with certain glues; and that plywood, made with a properly controlled grade of veneer having a limited amount of white pocket, is equivalent in strength to plywood made with the former "D" grade veneer.

The increased use of No. 2 sawmill logs and second-growth Douglas-fir has helped to stimulate industry interest in the practice of heating the logs before cutting veneer. Studies made by the Oregon Forest Products Research Center and the U.S. Forest Products Laboratory show a number of advantages for heating. Several older plants and at least three new plants now steam Douglas-fir bolts before peeling veneer. Plant representatives report improvements due to heating include less wear on the lathe, smoother and tighter veneer, and a higher yield of face veneer.

The Federal Housing Authority minimum property standards were revised November 1, 1958. At that time, structural plywood for subfloors and roof sheathing was divided into two groups: Douglas-fir and other western softwoods. In general, this FHA standard requires other western softwood plywood to be thicker than Douglas-fir plywood when used for the same span and load. For example, where ½-inch Douglas-fir plywood can be used, other western softwood plywood ⅝ inch in thickness is specified This has caused numerous problems in the manufacture and warehousing of softwood plywood. Recently the industry, under Douglas Fir Plywood Association leadership, has amended the Commercial Standard for Western Softwood Plywood CS122–56 and grouped the western softwoods in accordance with their strength and stiffness. Those in group one include western larch, western hemlock, noble, silver, grand, and California red fir, Sitka spruce, and Port-Orford-cedar. Panels made from these group one woods, except western larch, are to be 1/32 inch thicker than those of Douglas-fir. This special panel construction is designed to permit interchangeable use with Douglas-fir plywood for normal sheathing and subflooring applications. Plywood made from the other western softwoods will still need to be of the next nominal thickness in order to be used interchangeable with Douglas-fir plywood. This whole problem of strength of the western softwoods and hardwoods is being intensively studied by the U.S. Forest Service, the Douglas Fir Plywood Association, and other industry cooperators.

Literature

As indicated by the selective bibliography at the end of this report, there has been a flood of new literature during the past 2 years. This bibliography lists some of the more significant developments but does not pretend to be complete.

An example of the intensive research being conducted is the work going on in the cutting of veneer. Studies in this field are being made at the University of Missouri by Leny; at North Carolina State by Hart and Bethel; at the New York State College of Forestry at Syracuse by Bishop; at the Weyerhaeuser Technical Center at Longview by Collins; at the Canadian Forest Products Laboratories by Feihl, Peterson, and Northcott; at Yale University by Hoadley and Wangaard; in Sweden by Engelsson; in Finland by Kivimaa; in Russia by Voskresenski; in Czechoslovakia by Prusak; in Japan by Nakamura and Saito; in France by Coulombeau, Pouzeau, and Pradal, in Great Britain by Knight and Newal; in Austrailia by Gottstein; in Malaya by Burgess and Kumarasamy; in the Philippines by Orozco and Saros; in Pakistan by Salehuddin and Barefoot; in India by Narayanamurti; in Germany by Plath and Plath; and at the U.S. Forest Products Laboratory in Madison. All of this work is in addition to advances being made by manufacturers of lathes, slicers, and veneer knives. For example, R. Stem recently reported increased knife wear and a better veneer surface generated by knives having a high polish.

A sonic device for inspecting glue bonds inside plywood and other multilayer materials has been developed at the Ottawa Laboratory of the Forest Products Laboratories of Canada. The device will detect any area where an inner glue line is defective. This development is described in the August 1959 issue of the Forest Products Journal.

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Surface-Texture Measurements for Quality and Production Control[1]

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Compares surface textures of sawn, planed, molded, and sanded surfaces; presents surface-profile indices and suggests their use for quality control and waste prevention.

SURFACE CHARACTERISTICS OF WOOD AND wood products determine their use in many applications. Properties such as color, pattern, and texture are some of the characteristics that set wood apart from plastics, metals, and other materials. An understanding of these characteristics and their control is therefore important to the wood industry. Color and pattern can be controlled or varied by selection of species, specimen, and the surface to be machined, i.e., radial, tangential, or cross-section. Surface texture also depends on other variables, both controllable and uncontrollable—for example, the method of machining, and sharpness and type of tools.

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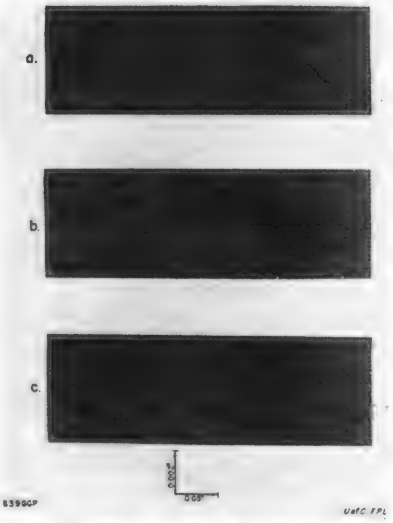

Fig. 1.—The surface profiles, as recorded by a stylus tracer, of three sawn surfaces: (a) small band saw; (b) common circular saw; (c) circular planer saw.

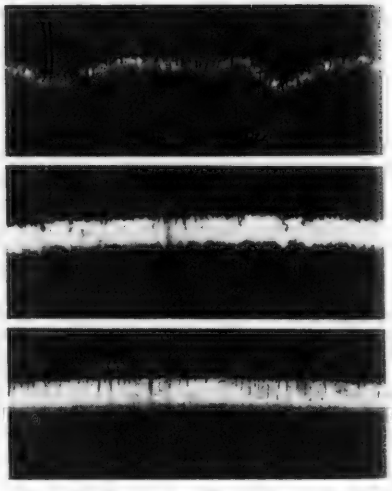

Fig. 2.—Surface profiles of sanded wood, obtained by light sectioning: (a) untreated; (b) sanded with grade 0 paper; (c) sanded with grade 00 paper.

Surface texture (surface roughness) may be described as the topography, roughness, or irregularity of the interface between the substance and its surroundings (generally air). Surface profile is a specific section normal to the surface texture. For a porous material such as wood, the definition of the surface, and thereby the surface texture, becomes difficult. The surface can be considered as a composite of several surface textures. The first-degree texture is attributed to anatomical structure; the second is produced as a characteristic of the manufacturing process; and the third is caused by variation within the particular manufacturing process (1).[2] The first degree surface texture is not a vari

[1] Presented at the FPRS 13th National Meeting, San Francisco, Calif., June-July 1959.
[2] Numbers in parentheses refer to Literature Cited at the end of the article.

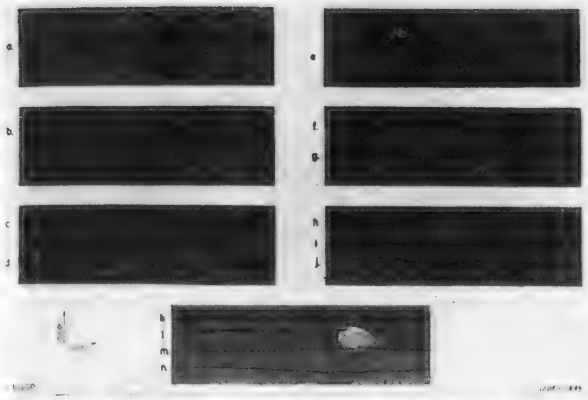

Fig. 3.—The step-by-step surface profiles of a finishing process on birch veneer. The surface and respective CLA indexes are:

untreated	80	h. lacquered 2nd coat	30
water-soaked	185	i. lacquered 3rd coat	15
wet hand-sanded	55	j. scraped	20
stained	125	k. rubbed, coarse paste	13
sealed	125	l. rubbed, fine paste	10
polished	65	m. cleaned	6
lacquered 1st coat	40	n. matted	10

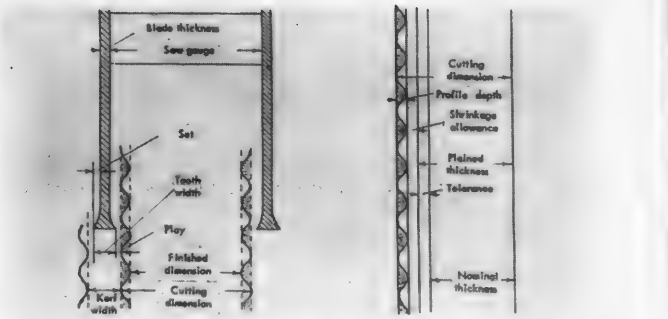

Fig. 4.—Variables affecting the dimension of sawn and planed lumber, showing the effect of surface profile on cutting and finished dimension.

able of the machining or production process, therefore, this paper will consider only the control of second- and third-degree surface texture.

The present status of the wood industry with respect to methods of surface-texture analysis and evaluation has been aptly stated by L. J. Markwardt (2): "Unfortunately there is, as yet, no instrumentation for precisely evaluating the smoothness or perfection of various machining operations so that visual methods of classification are relied on." Instruments and methods have been or are now being developed for this application. Many approaches have been proposed and tried, but the most favorable appear to be stylus tracers and light sectioning. Stylus tracers, in general, consist of a pickup that traces the surface with a mechanical or electrical connection and transfer the movement to a recorder. In light sectioning, a narrow line of light is cast on the surface at an angle, and the reflection is photographed. The reflection appears as a wavy line of light, the waves corresponding to the roughness of the surface. These and other methods have been discussed by Marian (3).

Three general index values are used in assessing the surface profile: center line average (CLA), root mean square (RMS), and peak-to-valley measure. CLA and RMS are mathematical measurements of the variances of the profile from a center line that is parallel to the general direction of the profile with the areas above and below equal. Peak-to-valley measurement is the average amplitude of the curve. Each provides a mathematical assessment of the surface profile which, in the case of stylus instruments, can be averaged automatically.

Surface Texture of a Sawn Surface

The surface texture of a sawn surface depends on the size, shape, and set of the teeth as well as on the saw and feed speeds. An increase in speed of the saw and number of teeth decreases roughness. An increase in feed rate increases roughness. The surface will appear as a series of ridges and sharp valleys, the depth of the valleys depending on the amount of set in the teeth. Superimposed on this texture is another composed of broken and torn cells attributed to the sharpness and type of tooth. Fig. 1 shows sawn surfaces prepared by three methods: a) small band saw, b) common circular saw, and c) circular planer saw. The surface-profile index values (CLA) were 290, 120, and 60, respectively.[3] Larger saws would give correspondingly greater surface-profile index values. Thunell (4) found an average peak-to-valley depth of 0.5 mm. in a survey of lumber sawn on a Swedish gang saw.

Surface Texture of Planed and Molded Surfaces

Planing or molding will give a surface texture that appears as a series of waves, transverse to the feed direction, their size and spacing depending on the number of knives, feed rate, knife speed, radius of knives, and depth of cut. Paralled to the direction of feed will be ridges and valleys caused by nicks and mars on the blades. A sharp blade would give a surface free from the second type of defect. A randomly-oriented roughness will be superimposed on the other two textures, as a result of broken and torn cells caused by the sharpness of the blade and its shape. Sieminski (5) has shown that roughness is greater when cutting perpendicular to the grain than when cutting parallel, with greater roughness occurring on softwood than on hardwood. It has also been shown that width of surface ripples increases with feed rate and decreases with cutter head speed and number of knives. The depth of the ripple, and therefore the surface, are dependent on the width of the ripple. The CLA of an average planed surface is 60.

Surface Texture of Sanded Surfaces

A sanded surface is characterized by a pattern of valleys aligned with the direction of movement of the paper across the wood. Their size and shape depend on the grade of sandpaper, speed of the sander, and the feed rate. A typical sanded surface gave a CLA of 60. Fig. 2 illustrates the effect of grade of sandpaper on the surface profile. These profiles were obtained by light sectioning. In each case the upper edge of the line of light indicates the quality of the corresponding surface.

Applications

To control the surface of a wood product, the surface texture must be determined and analyzed. A series of tests with a surface-texture measuring device would determine a standard for different processes and products. Then the process could be controlled by standard quality control methods. Any variation from this standard would be observed and the process adjusted to compensate.

In an operation like gluing or finishing, a maximum or minimum allowable surface-profile index could be established, to which incoming material should conform. Work has been done on determining the correlation of surface texture to adhesion. Janson (6) and Marian *et al.* (1) have shown that strength of the joint depends not only on surface texture but also on method of preparation. By eliminating the surface preparation variable, a relationship between surface texture and joint strength can be determined for various operations.

[3] Values and graphs obtained with Taylor and Hobson "Talysurf" with "Talymin" attachment.

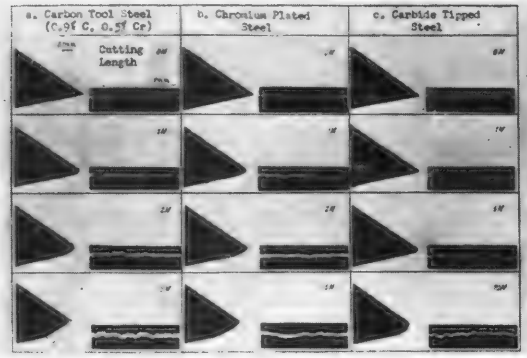

Fig. 5.—A comparison of the sharpness of planer blades of three different steels and their corresponding surface profiles on birch, as recorded by light sectioning. The blades were dulled by cutting hardboard.

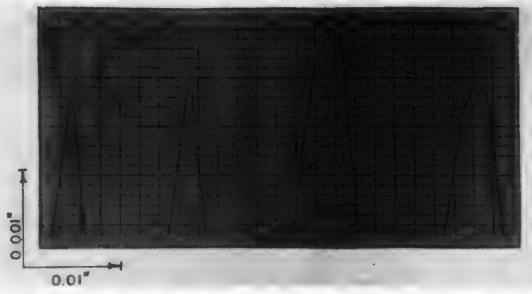

Fig. 7.—Graphs show profiles of cutter head knives, taken across the edge. The first two were taken on a sharp knife, the other two on the same knife after it was dulled.

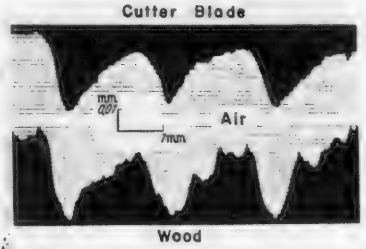

Fig. 6.—Profile of a cutter blade along its edge, and the corresponding profile produced on the wood surface.

When these values are found, the surfaces to be glued can be controlled to obtain the highest strength values.

A finishing department could use surface-texture measurements to control the roughness of material as it passes from one finishing operation to another. Fig. 3 illustrates the step-by-step surface profiles of a finishing process and gives the corresponding index values. The ideal value could be found and used as the standard in controlling each step of the process.

Another application of surface texture measurement is its usefulness in waste prevention and determination of accuracy of cut. The surface-profile index is a direct measure of the amount of board to be removed in order to obtain a smooth surface. Thunell (7) shows graphically the importance of surface profile with respect to waste (Fig. 4). He indicates that the surface profile is important in determining the cutting dimension and, along with the kerf width, in determining the waste in the sawing and subsequent planing operation. Thus by controlling the surface-profile index, as well as kerf width, to a minimum value, the waste can be minimized. This also points out the necessity for defining surface texture when attempting to discuss board dimensions. In some applications the critcial thickness would be the finished dimension, and in others, the cutting dimension.

Surface-texture measuring instruments can also be of great importance to the wood industry by providing a quantitative measurement of tool sharpness.

Kollmann (8) states that for sawn surfaces, dull teeth will increase roughness. A wild tooth would also increase the roughness. This relationship has also been shown for other machining methods. Fig. 5 shows work done by Thunell (4) with planer blades. The blades and their respective surface profiles are shown for three different steels, and indicate the result of dulling on the surface texture. Mang (9) investigated the wear of cutter head knives by a glue line, and showed the correlation that exists between surface texture and blade sharpness. For his studies of blade damage, he measured the blade edge directly, but exhibited the comparison of the blade surface to the surface profile of the wood produced (Fig. 6).

The direct relationship between surface texture and tool sharpness provides an excellent method of controlling the latter. Once the surface-profile index was determined for a given operation, the blade would be changed whenever that limit was reached. The limit would be set by the quality of the surface needed or, in an operation for which the surface texture was not critical, by the point most practical from the standpoint of the sharpening and cutting operation. In some operations, it might be advantageous to measure the edge of the blade directly. This can be done either along the edge (Fig. 6), to determine the nicks and mars, or across the edge (Fig. 7) to show the edge profile.

Summary

Surface-texture measurements can be of great importance in quality control of wood products. The desirability of a smooth surface is without question in most applications, especially in such fields as gluing and finishing. Although it is possible to judge a surface by inspection, more accurate measurements, which can be obtained only by surface-texture instruments, are necessary.

The variables in machining processes are such that they can be measured and controlled, to a large extent, by surface graphs and surface-profile indexes. It is possible to set up control limits of surface-profile indexes to which wood to be used for gluing, finishing, and other operations must conform. Surface-texture measurements can be used to control waste in remanufacturing operations. It is essential to have an understanding of surface texture when discussing accuracy of cut and board dimension. Surface texture is a direct indication of tool sharpness and tool damage, and therefore offers a method of quantitatively controlling tool condition.

The applications of surface-texture measurements in quality and production control in the wood industry are wide and varied, and the industry can profit economically by their development and utilization.

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Chemical Conversion of Wood Residues, Part III:

Preparation and Properties of Hydroxymethylfurfural[1,2]

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From viewpoint of chemical conversion of wood residues, hydroxymethylfurfural is a potential product of great versatility. Here is a new procedure for obtaining experimental quantities of the material and a discussion of its properties.

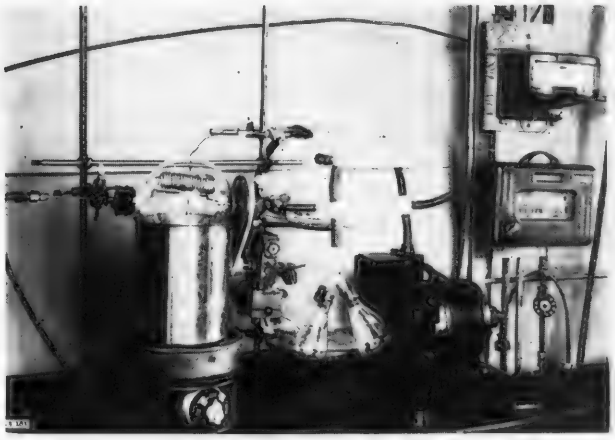

Fig. 1.—High-vacuum rotating laboratory still with internal condenser.

Recent research on chemical utilization of wood at the Forest Products Laboratory has been concerned with the various reactions of cellulose and sugars in aqueous acidic solutions. Rate and yield data have been collected over wide ranges of reaction conditions. This information can be used to evaluate the economic possibilities of various processes proposed for the saccharification of wood or for the production of chemicals from cellulose or crude wood sugar solutions. Because the cellulose fraction of wood is composed principally of glucosan, the sugar glucose has received considerable attention.

Glucose heated in the presence of mineral acid undergoes decomposition, resulting in the formation of a large number of chemical compounds of several classes. The main course of the reaction, however, is through a mechanism producing hydroxymethylfurfural and levulinic acid and prominent among the compounds produced are those containing the furan ring. Compounds of this group known to be present (8, 5, 10, 1)[4] are 5-hydroxymethylfurfural, its ether, oxybis(5-methylenefurfural), and 2-hydroxyacetylfuran. The relative quantities of each present depend of course upon the conditions employed. In dilute acidic aqueous solution hydroxymethylfurfural predominates. The reaction of glucose is in many respects analogous to the reaction of xylose when furfural is produced. A significant difference, however, is the fact that the stability of hydroxymethylfurfural during preparation is much less than that of furfural during its preparation.

Hydroxymethylfurfural and related compounds are found in many glucose solutions of industrial importance. For instance, hydroxymethylfurfural occurs in hydrolyzed starch solutions, being one of the impurities that is removed prior to the production of crystalline corn sugar. It is present as one of the reacting materials which produce the discoloration of sugar solutions during heating, a phenomenon referred to as "non-enzymatic browning." Undoubtedly, hydroxymethylfurfural and related compounds are present in pulping liquors, as this group seems to be largely responsible for the difficulties encountered when using ultraviolet analytical techniques to follow the course of pulping reactions. The strong ultraviolet absorption properties of hydroxymethylfurfural interfere with lignin analysis by this method. The low quality of the wood sugar solutions produced by the acid hydrolysis of wood is due primarily to the presence of large amounts of impurities made up of chemical components derived from hydroxymethylfurfural.

Despite its wide-spread occurrence, hydroxymethylfurfural is usually present only as a troublesome impurity in low concentration. This is because it is very reactive and under favorable conditions for its formation it undergoes subsequent reactions resulting in the formation of other compounds and polymers. This high reactivity makes hydroxymethylfurfural a compound of considerable interest to the chemist and since its discovery in 1895 (2) an extensive literature has accumulated (3). Work related to its structure and properties was done by Dull and Kiermeyer (2, 8) and a group in Amsterdam led by Blanksma and Van Ekenstein (12). Among the contributions of a later group is a paper by Middendorp (9) which is outstanding. In the 1940's an English group, supported by the Sugar Research Foundation, undertook studies with the hope of eventually producing the compound from sucrose (11, 5, 6). This work was discontinued before reaching the pilot plant stage. Currently several American chemical companies are actively engaged in studying the potential markets and methods of production. Recently the announcement was made that hydroxymethylfurfural and some derivatives could be obtained in pilot

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[1] Presented at the Forest Products Research Society Annual Meeting in San Francisco, Calif., June 28-July 3, 1959.

[2] This study was supported by a grant from The Quaker Oats Company.

[3] Maintained at Madison, Wis., in cooperation with the University of Wisconsin.

[4] Numbers in parentheses refer to Literature Cited at the end of this article.

plant quantities for development studies (4).

Commercial interest in hydroxymethylfurfural stems from the polyfunctional character of the molecule. It undergoes the expected reactions of alcohols and aromatic aldehydes as well as ring cleavage reactions resulting in unsaturated straight chain compounds. The hydroxyl group is very reactive; heating at 250° C. results in condensation with the formation of the ether, oxybis(5-methylenefurfural) (9). This versatility makes possible the synthesis of ethers, glycols, dialdehydes, acetals and other organic intermediates which in turn can be used to produce many chemical products such as surfactants, resins, plasticizers and agricultural chemicals. From the point of view of the chemical ulitization of wood, hydroxymethylfurfural is a potential product of great versatility that could be produced as a coproduct with furfural and levulinic acid. These three compounds, all of which can be obtained from wood, can be reacted to produce a variety of products spanning the entire chemical product field. Whether the manufacture of these products can successfully compete with that of present day products of the petrochemical industry will not be known until intensive studies of production methods, yields, and product quality are made.

To obtain experimental quantities of hydroxymethylfurfural by the method reported by Kiermeyer (8) requires the use of pressure equipment. This method is also time consuming and limited to small quantities when working with the ordinary laboratory equipment. A new procedure, presented here, was developed in an effort to eliminate these difficulties.

Hydrolysis of Sucrose

The reactor used as a 10-gallon stoneware crock fitted with a heating coil of 14 feet of ½-inch copper tubing and a large air-driven stirrer. For a reactor of this size the starting solution would contain 30.6 pounds of water, 30.6 pounds of sucrose, and 9.2 pounds of sodium chloride. The solution is brought to the boiling point (107° C.) by passing steam into the copper coil. When boiling begins 350 milliliters of HCl are slowly added and the reaction allowed to proceed while maintaining rapid stirring with the temperature held at the boiling point. At these concentration levels the reaction is exothermic and should not be carried out in a confined vessel. Precisely 25 minutes after the HCl catalyst has been added the reaction is quenched by the addition of 7 pounds of crushed ice and cold water turned into the cooling coil after turning off the steam. The solution is brought to room temperature and neutralized with a 33-1/3 percent solution of sodium hydroxide. This should be done carefully, maintaining rapid stirring and introducing the caustic near the stirrers to avoid a localized high pH. Hydroxymethylfurfural is very unstable in alkaline solution and overshooting the desired pH 7.0 will result in substantial loss. After neutralization the solution is decanted through a crude glass wool filter to remove humins and carbonaceous product. One-half pound of Celite No. 545 filter aid is added and the solution filtered. In the laboratory preparation a Buchner funnel with a precoated filter paper of medium porosity (E and D 617) was used. The liquid is very viscous and difficult to filter if not handled as instructed. The concentration of the desired hydroxymethylfurfural at this point is 4 to 5 milligrams per milliliter and the total content of the solution is about 3½ pounds.

Extraction with Solvent

Of the various solvents considered for extracting the hydroxymethylfurfural from the clarified solution, ethyl acetate seemed to be the best suited. The distribution coefficient of hydroxymethylfurfural between the solvent and aqueous phase is 1.50. Values of the distribution coefficients for several other solvents are given in a thesis by Keller (7). The extraction is performed in a continuous extractor in which the solvent is distilled from the extract and returned for reuse. The laboratory appartus consisted of a 2-liter calandria-type glass evaporator capable of evaporating and recycling approximately 200 milliliters of ethyl acetate per minute when operating under a vacuum low enough to maintain a boiling point of between 35° and 40° C. The condensed ethyl acetate from the evaporator was fed into and near the bottom of a 5-gallon bottle containing the filtered solution where it was thoroughly mixed by an air-driven stirrer. The extract was continually separated from the raffinate in a small settling flask and returned to the evaporator. Thus the extracted hydroxymethylfurfural was concentrated in the evaporating section. When recycling ethyl acetate at a rate of 200 milliliters per minute this equipment could theoretically extract the hydroxymethylfurfural from 5 gallons of solution in 2 hours. In practice, after extracting 3 hours an estimated 75 percent of the hydroxymethylfurfural generated in the first step of the procedure can be recovered in the ethyl acetate fraction.

After extracting for 3 hours the extraction portion of the equipment was disconnected and solvent removed from the extract phase in the evaporator. The temperature was not allowed to exceed 50° C.

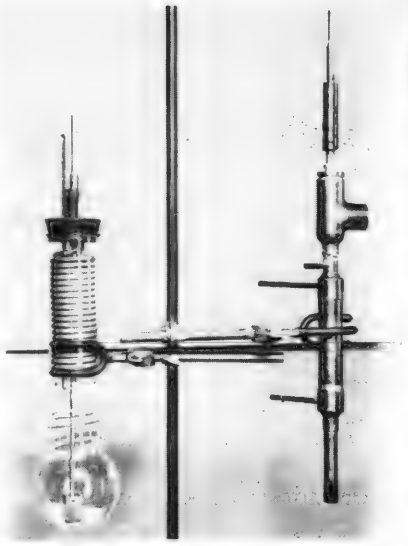

Fig. 2.—High-vacuum laboratory stills: Left: "Hickman" still; right: "Spinning Ribbon" still.

Distillation

The concentrated extract is now washed with a saturated solution of sodium carbonate and charged to a distillation unit. The apparatus used is shown in figure 1. Here a forerun of ethyl acetate and water is removed by reducing the pressure to 12 to 15 mm. Hg and gradually raising the temperature to 90° C. As the vacuum is allowed to decrease hydroxyacetylfuran distills and condenses as a solid. Later the hydroxymethylfurfural distills at a pressure of 100 microns. The purity of the product from the first distillation is from 85 to 95 percent hydroxymethylfurfural. Upon redistillation a purity of 99+ percent can be obtained with good recovery.

The still shown in figure 1 is a rotary type made from a 2-liter round-bottom flask. It rotates at 50 revolutions per minute in a heated glycerol bath. The still temperature differs only slightly from the bath temperature. The stainless steel tubing condenser is within the vapor space and the distillate is withdrawn as a liquid. This eliminates the pressure drop from still pot to condenser with a resulting drop in boiling temperature and increase in productivity. The rotary seals are rubber stoppers and brass pipe with machined projecting ridges. Distillations were made in this equipment at a rate of 90 to 225 cubic centimeters per hour with bath temperatures at 116 to 128° C. and pressure readings at 60 to 80 microns.

Two other types of distillation equipment were tested. One was a "Hickman" type still equipped with a large stirrer and condenser. It is

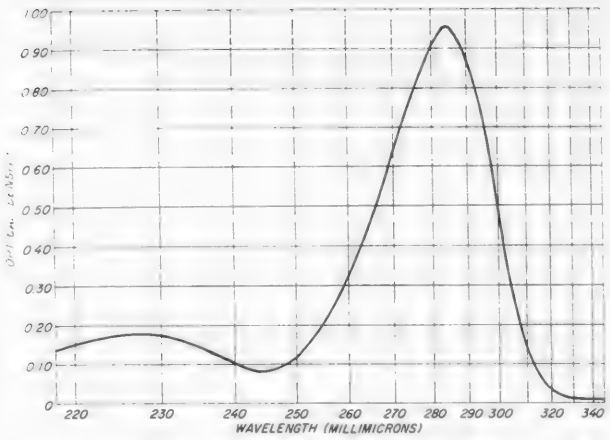

Fig. 3.—Ultraviolet absorption spectra of an aqueous solution of hydroxymethylfurfural at concentrations of 7.11 milligrams per liter.

Table 1.--Comparison of ultraviolet extinction coefficients for aqueous hydroxymethylfurfural solutions

Solutions	Minor maximum:		Minimum		Major maximum	
	mμ	ε[1]	mμ	ε[1]	mμ	ε[1]
Forest Products Laboratory preparation	228.0	3,053	245.0	1,595	283.0	16,924
(2)	230.0	3,080	.....	.....	284.0	16,700
(3)	228.0	1,900	245.0	1,030	282.5	16,900
(4)	230.0	3,221	245.0	2,114	284.0	16,830
(5)	.....	.....	.....	.....	285.0	16,500

[1] Units of ε are liters per gram-molecule per centimeter.

[2] Singh, B., Dean, G. R., and Cantor, S. M. 1948. Journ. Amer. Chem. Soc. 70, 517.

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[5] Wolfrom, M. L., Schuetz, R. D., and Cavalieri, L. F. 1948. Journ. Amer. Chem. Soc. 70, 514.

shown on the left in figure 2. It has the apparent advantage of a low pressure drop from the boiling pot to the condenser. Unfortunately, even with rapid stirring, the material in the still tended to spatter slightly resulting in product contamination. Similar equipment with a much larger space above the liquid would work satisfactorily but would have to be large to handle pound quantities.

The "Spinning Ribbon" type still shown on the right in figure 2 was also tested. It is constructed from simple copper water pipe fittings. The "ribbon" is a ½-inch-wide piece of 20-gage stainless steel hung on a 1/16-inch-diameter wire by means of which it is rotated. The rubber tubing seal can be seen at the top. This still operated satisfactorily when heated to 120° C. with the ribbon spinning at approximately 400 revolutions per minute.

Purification

A sample of high purity suitable for standardizing analytical techniques and measuring physical properties was prepared in the following manner:

Two hundred and seventy grams of hydroxymethylfurfural of 87 percent purity were completely solidified. The material was then allowed to melt slowly until a residue of approximately 50 grams of solid remained. During the melting, the liquid was allowed to drain from the solid, thus being removed from contact with the higher purity crystals. The solid was placed in a stainless steel crucible with a fritted stainless steel bottom and centrifuged, then washed and centrifuged three times using a total of 100 cubic centimeters of petroleum ether (boiling point 40° to 65° C). Fifteen grams of the washed crystals were dissolved in 75 milliltiers of diethyl ether. Then 425 milliliters of the petroleum ether were added and the mixture shaken well. The top, colorless layer of ether-petroleum ether was de-

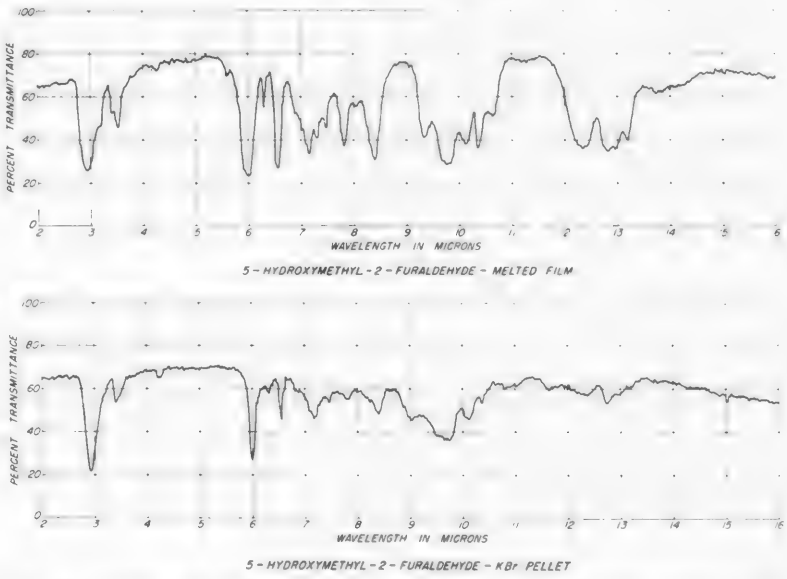

Fig. 4.—Infrared spectra for Forest Products Laboratory reference hydroxymethylfurfural. Top, liquid form; bottom, potassium bromide pellet.

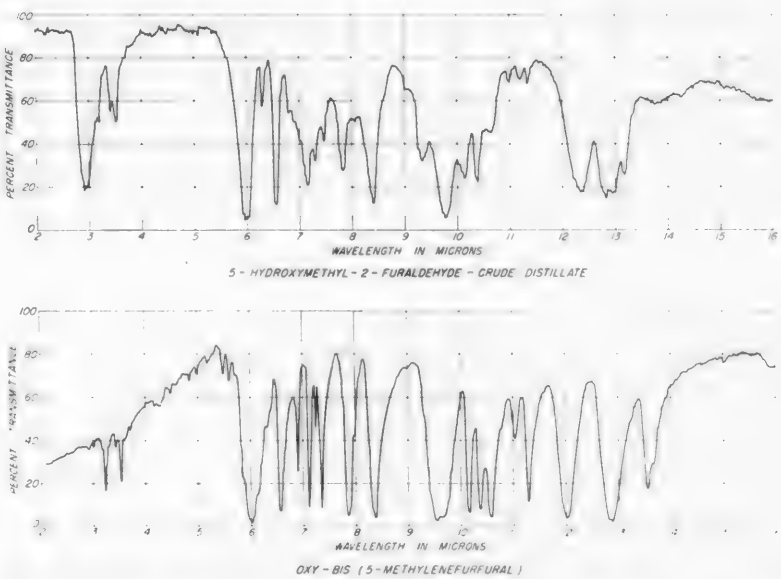

Fig. 5.—Infrared spectra. Top, crude distillate of hydroxymethylfurfural from ethyl acetate extract (KBr pellet); bottom, oxybis-5-methylenefurfural) (KBr pellet).

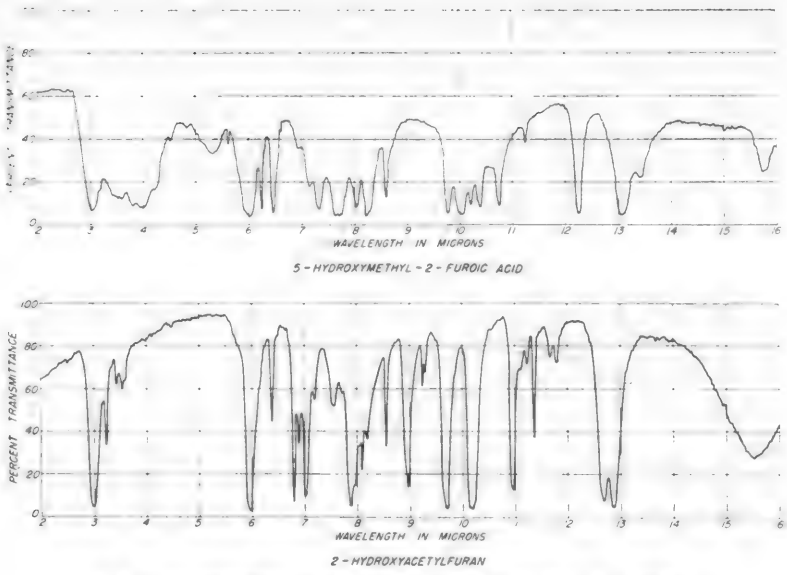

Fig. 6.—Infrared spectra. Top, 5-hydroxymethyl-2-furoic acid (KBr pellet); bottom, 2-hydroxyacetylfuran (KBr pellet).

canted and refrigerated at 0° C. After cooling the mixture, crystallization was initiated by scratching the glass and refrigerating at –20° C. The mixture was allowed to equilibrate for several days at –20° C. The crystals obtained were beautiful needles, very fine and long, hairlike in quality, and soft and friable. They were broken with a glass rod, the liquid decanted, and the damp solid transferred to a cold porous plate. Free liquid was removed from the crystals by pressing and turning on the plate. The crystals were transferred to a number of tared glass tubes in quantities ranging from 8 to 150 milligrams per tube. The transfers were made at –20° C. with all equipment at ambient temperature. The loaded ampoules were bundled together and dried overnight at 25° C. and 0.5 millimeter Hg in an Abderhalden drier with Ascerite as a desiccant. The drier was brought to atmospheric pressure with dry nitrogen. The tubes were sealed by removing them individually from the nitrogen atmosphere, connecting directly to a water aspirator, and sealing immediately.

Properties

Duplicate combustion analysis of this material indicated 57.32 percent carbon and 4.71 percent hydrogen; the theoretical values are 57.14 percent carbon and 4.80 percent hydrogen. The melting point was determined to be 33.4 ± 0.15° C.

The ultraviolet absorption spectra made with a Beckman DU spectrophotometer is shown in figure 3. A comparison of the important extinction coefficients with values given in the literature is shown in table 1.

Figure 4 shows the infrared spectra pound might be expected when handled in the conventional manner. The chemical was found to be extremely light sensitive and the pure material for the reference sample as the melted film squeezed between plates and also in potassium bromide pellet form. Although these are not on a comparable quantitive basis, it is obvious that the potassium bromide technique destroys a great deal of the spectral detail.

Figures 5 and 6 are reproductions of the spectral curves for the original crude hydroxymethylfurfural, from which the reference sample was obtained, and for three possible contaminants of hydroxymethylfurfural preparations. The significant differences between the crude and pure hydroxymethylfurfural spectra occur at 1,100 $cm.^{-1}$ and in the region 880 to 910 $cm.^{-1}$ where three distinct bands occur in the crude sample. The presence of 2-hydroxyacetylfuran and of the ether in the crude account for all the differences excepting absorption band at 898 $cm.^{-1}$.

Storage tests were conducted to determine what losses of the com degrades rapidly when stored in transparent containers. If stored in the dark, storage life is good even at temperatures to 100° F. One might expect to make shipments in tank cars or opaque containers with no added stabilizers without appreciable loss. The mechanism of the decomposition is not understood but suitable additives could probably be found that would make losses due to decomposition inconsequential.

Probable Costs and Uses

The Forest Products Laboratory has carried out preliminary experimental work on the screening of various catalyst systems for the conversion of glucose to hydroxymethylfurfural. On the basis of these data cursory economic evaluations were made of the cost of producing from various raw materials. There appears to be an excellent possibility of producing hydroxymethylfurfural in a large-scale industrial operation at a competitive price with other organic intermediates but whether wood can compete with other carbohydrate sources as the raw materia will require more experimental work

To the synthetic organic chemist hydroxymethylfurfural is an exceptionally interesting substance becaus of the many reactions it may undergo Having both an aldehydic and an alcoholic group it reacts normally both as an aldehyde and an alcohol. Reactions with these groups followed b ring cleavage offer unique possibilities, for the products are straight chain molecules with numerous reactive sites. When these reactions ar recognized and the variety of ways in which they may be used are appreciated, hydroxymethylfurfural become a rich mine of possibilities from which a large variety of chemical product can be made. Development of practica applications for this interesting material have been hindered by the difficulty of obtaining an ample supply of good quality.

It is hoped that the preceding information will stimulate interest in this chemical and be followed by experimental work that will establish it as a commercial product.

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Polyurethane Coatings for Wood

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Toughness and abrasion resistance are outstanding characteristics of these coatings; two-package systems, short pot life, pigmentation problems, and toxicity will limit uses.

ALTHOUGH THE BASIC CHEMICAL reaction of the polyurethane coatings has been known more than 90 years, it is only during the last few years that coatings of this type have been exploited. Frequently, something new is glamorous simply because it is new. Let's attempt to strip this "newness" glamour from the polyurethane coatings and see if they have application as finishes for wood.

It has been established that the outstanding toughness and abrasion resistance, together with good chemical resistance of the polyurethanes will find utility in the coatings industry. Undoubtedly, there are numerous applications where these properties are required.

It is not proposed to explore and develop the many chemical reactions involved, or that are possible. Basically, the urethane linkage is the result of the chemical reaction of an isocyanate group (–N–C–O) with an hydroxyl group (–OH) in this fashion:

$$RNCO + R'OH \longrightarrow R\text{–}NHCOOR'$$

Many different starting materials can be used. Toluene diisocyanate has been found to be the optimum source of the isocyanate group for this reaction, but the hydroxy group can come from any one of a wide number of polyhydroxy compounds. Trimethylol propane and 1,3 butanediol are frequently used. The properties obtained from these coating materials are greatly influenced by the type of polyhydroxy compound used in the reaction. This is especially true of the hardness versus flexibility balance.

There are five types of polyurethane coatings now in use.

1. A two-package system of toluene diisocyanate and polyhydroxy compound that is mixed just before application and cured at room temperatures.
2. A two-package system of reacted diisocyanate resin, whose reactivity has been chemically terminated, and a catalyst such as a tertiary amine or a metal compound such as cobalt napthenate that is mixed just before application and cures rapidly at room temperature.
3. A one-package finish where the more reactive groups of the toluene diisocyanate are chemically blocked. The finish is applied, then heated to 285° F. or more to release the blocking agent and allow the polymerization to proceed.
4. A one-package system where the diisocyanate polymer has had its reactive groups terminated chemically. This material is applied and reacts with moisture from the air to produce the curing.
5. A one-package system that is essentially a drying oil reacted with diisocyanate to upgrade speed of dry, hardness and abrasion resistance.

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Toughness and Abrasion Resistance

Initial reference was made to the outstanding toughness and abrasion resistance that characterize these coatings. A polyurethane coating, properly formulated, produced, handled and applied, gives a clear finish on wood that is so tough that marring of the finish is almost impossible.

The best demonstration of abrasion resistance is by means of the Taber Abrasion Test, where the polyurethanes are from two to twenty times better in wear resistance than conventional finishes.

Chemical Resistance

In comparison with the conventional finishes that have been used for many years, the polyurethanes are great improvements in chemical resistance. In general, strong solvents such as esters and ketones will swell the coatings but will not dissolve or degrade them. Polyurethanes resist caustics and dilute acids, but strong concentrated acids will attack the film. In general, polyurethanes have a higher moisture vapor transmission rate than most conventional clears; this is considered to be an asset in exterior application over wood.

Advantages and Disadvantages

It is highly unfortunate that we cannot have these outstanding advantages without some degree of sacrifice in other properties. Whether or not the particular limitations are important to the specific problem at hand at the time depends upon individual factors, some of which cannot be controlled. The two-package systems outlined above have short "pot life"; they must be applied shortly after mixing, usually within 8 hours. This means that the two components must be kept apart until just before use, and material that is mixed one day may not be used the following day, but would have to be discarded.

The polyurethane finishes tend to yellow more on exposure to outdoor weathering or direct light than many conventional types of finishes. Outdoor durability of a polyurethane clear coating is not very good unless an ultraviolet light absorber is incorporated in the finish. Properly protected in this manner at the time of formulation, the polyurethane clears give a reasonably good account of themselves on outdoor exposure. There are reports of outstanding performance in tidewater immersion.

Generally, the adhesion of polyurethane coatings to untreated wood is outstanding. Likewise, the adhesion to certain other substrates is very good, including cement, cinder blocks, plastics in general, copper, and nickel. Adhesion to steel is only fair and adhesion to an oil coating such as a wood filler is quite poor. Fortunately, the excellent build of polyurethane coatings usually precludes the need for fillers, even on open grain wood.

Very specialized problems are encountered by the paint formulator in attempting to pigment the polyurethane clears. These problems act to limit the color range and hiding level of pigmented coatings.

Toluene diisocyanate is considered to be a toxic chemical. In a properly

[1] Presented at the Wood Finishing Session, FPRS 13th National Meeting, San Francisco, June-July 1959.

formulated polyurethane coating, the toluene diisocyanate is tied up during the reaction so that none is free to produce toxic reactions. However, the possible presence of unreacted toluene diisocyanate must always be considered. Also, the chemicals used to block the reactive groupings on the toluene diisocyanate and that are subsequently volatilized by heat are usually materials with certain toxic aspects. Accordingly, ample ventilation of baking facilities is required and the air discharge from the oven must be safely dissipated.

Basically, the polyurethane coatings are more expensive than the conventional type of clear coatings. This is due primarily to the cost of the raw materials from which the coatings are made and, to a lesser extent, to the manufacturing processes necessary.

As would be expected from the resistance properties of the cured polyurethane coating, brushes, spray guns and other application tools must be cleaned immediately or the cleaning becomes almost impossible.

The polyurethane materials are already being used in foams, wire enamels, and in clears for non-metallic substrates. Also, an outstanding synthetic rubber has been produced from polyurethane, but, so far, the economics are quite unfavorable.

It is expected that the use of the polyurethanes in the first three categories will continue to expand. Where the outstanding properties of toughness and abrasion resistance are required, the polyurethane coatings are now among the best finishes obtainable.

Supplemental Bibliography — on Glues and Gluing

Supplemental Bibliography

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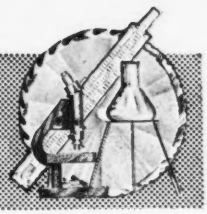
Abstracting the Literature



PARTICLE BOARD

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The effect of initial moisture content (*I*) of particle-board mats on the relationship between hot-press time and curing of the urea-resin binder (as detd. by the thickness stability of the board and the cleavage strength of the central layer) was studied. The hot-press time to reach a given thickness increased with increasing (*I*). Shrinkages on further hot pressing was greater at higher I. Cleavage strength increased to a max, and then decreased with pressing time. The max. was reached faster at low *I*. The highest strength was obtained with a *I* value of 14%. [A.B.I.P.C. 30:3]

Ota, Motoi, and Tsutsumi, Juichi. Studies on particle board produced from planer shavings. II. The influences of the curing cycle and the beginning time of the breathing period on the properties. J. Japan Wood Research Soc. 5. no. 3: 92–5 (June, 1959). [Jap.; Engl. sum.] *cf.* A.B.I.P.C. 29: 559.

The effects of curing time (7, 10, 15, and 20 min.) at 120°C. platen temp. and start of 1-min. breathing periods (3, 5, and 7 min. after initial compression) on the phys. and mech. props. of wood-shavings boards contg. 4% resin (applied from 35% aq. solns.) were investigated. Curing time had no effect on bending strength. Board thickness decreased with prolonged curing, but thickness variations became smaller. Hygroscopicity was improved by prolonged curing times, but was unaffected by the interval before breathing. Bending strength and hardness were improved by delaying the onset of breathing, whereas thickness was decreased. [A.B.I.P.C. 30:3]

HARDBOARD

Nakano, Ryoji, and Kadita, Sigeru. Studies on the varation of properties in harboard. I. Variation of bending strength in hardboard manufactured on the fourdrinier machine. Wood Research (Kyoto) no. 21: 73–81 (March, 1959). [Jap.: Engl. sum.]

Fourdrinier hardboard specimens (13 cm. by 5 cm. by 1/8 in.) of four types (heat-trd. and untrd. and spanned parallel or normal to the machine direction) were conditioned for 1 month at room temp. and 65% R.H. and tested for bending strength. sp. gr., thickness, and moisture content. Variations in bending strength sp. gr., and thickness were less than those reported by F. Kollmann (*cf.* B.I.P.C. 28: 1508–9). A const. linear relationship was found to exist between sp. gr. and bending strength, but not between sp. gr. and thickness in each of the four board series. Hardboard quality might be further improved by greater attention to web formation and heat trmt. in the mfg. process. [A.B.I.P.C. 30:3]

DIMENSIONAL STABILIZATION

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Samples of Japanese cypress and birch were pretrd. with 2% boric acid soln. or in an atm. of hydrogen chloride, then conditioned for 40 days, and reacted with formaldehyde vapor at 95°C. for 20 hr. Boric acid had no effect as catalyst, whereas hydrogen chloride effectively improved the dimensional stabilization of the wood by formaldehyde, as well as the anisotropy and hygroscopicity, without increasing the sp. gr. or the color of the wood. However, the acid caused some wood degradation. Formaldehyde without catalyst restore part of the swelling ability lost on heat trmt. of the wood; this is probably a bulking effect, caused by the temporary polymerization of free aldehyde in the wood. Heat trmt. without formaldehyde had no stabilizing effect. [A.B.I.P.C.] 30:3

PULPING

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The lengths and widths of the tracheid cells of pine *(Pinus silvestris)* and spruce *(Picea abies)* and of the libriform and vessel cells of white birch *(Betula pubescens)*, common birch, *(B.-verrucosa)*, mountain birch *(B. tortuosa)*, black alder *(Alnus glutinosa)*, gray alder *(A. incana)*, oak *(Quercus robur)*, and aspen *(Populus tremula)* were measured with a curvimeter at 60× magnification. The cells were isolated from kraft pulps of the respective chips taken from 25–35 yr. old trees at a height of 1–3 m. When plotted on normal probability paper, the fiber lengths were found to be normally distributed for all wood species studied, except white and common birch. These two species showed a slight positive deviation from the normal distribution plot in the short-fiber range. The deviation may have been due to the inadvertent inclusion of other cell types, e.g., tracheid cells, closely resembling the libriform cells. The libriform cells of white birch were 13% longer than those of common birch; this morphological difference may be worth remembering when considering the two species for industrial utilization. 1 table, 2 figures, and 8 references.

C.L.B.

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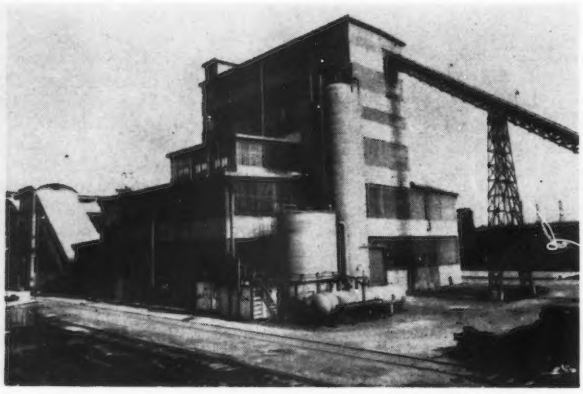
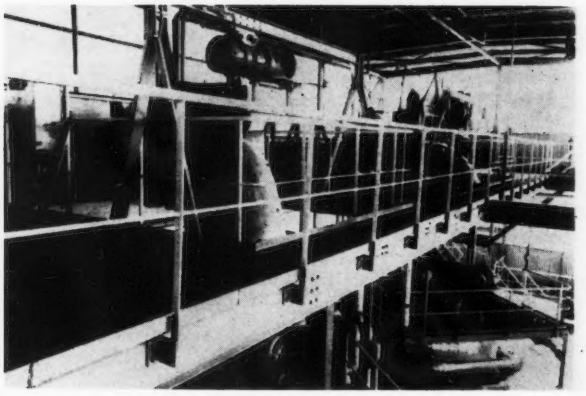
Chemi-Groundwood Pulp Mill Utilizes Hardwoods for Newsprint



Europe's first chemi-groundwood plant built at Corbehem, France for Societe F. Beghin, S. A.



Interior of chemi-groundwood mill designed to produce newsprint pulp from European hardwoods.

The French call it "pate chimico-mecanique." In English, it is called a chemi-groundwood plant. In either language, it describes the first plant of its kind built in Europe to meet the needs of European newsprint manufacturers for pulp.

The chemi-groundwood plant, designed to produce 100 tons of hardwood pulp a day, was built in France for the Societe F. Beghin S.A. at Corbehem, France, in the Pas de Calais area by the Stone & Webster Engineering group.

Permits Use of Hardwoods

The Beghin chemi-groundwood mill represents a pioneering contribution to the European pulp and paper industry because it provides an answer to the problem of uitlizing economically the hardwood trees, from forests having an abundance of this raw material.

In most accessible areas, the softwood trees have been largely cut and conveyed to the paper mill because softwood is easier to process in the existing pulping plants. The hardwood trees have been left standing. In these areas the woodcutters had already installed expensive equipment for conveying out the softwoods which are now largely depleted. The hardwoods are not only available but have reseeded the cut areas and these new trees grow to papermaker's maturity in only 20 years.

Saves Electric Power

The chemi-groundwood process used in the Beghin Plant in Corbehem, France, pressure cooks whole hardwood logs in a neutral sulphite solution, and after cooking they are ground in a conventional softwood grinder. The cooking loosens the lignin bond so that wood fibers are actually pulled off the log without appreciable damage together with the lignin surrounding the fibers so that the total bulk is still present. This requires less grinding horsepower, thereby resulting in considerable savings in electric power and initial investment. Still another advantage of chemi-groundwood is its tear strength which is greater than regular groundwood, thereby making it possible to produce a satisfactory newsprint from a blended stock of groundwood, chemi-groundwood and a reduced percentage of sulphite pulp.

Ilija Devic, Technical Director, Wood Industry, Combined Works, Novi Sad; Ivo M. Horvat, Forest Faculty, University of Zagreb, Yugoslavia.

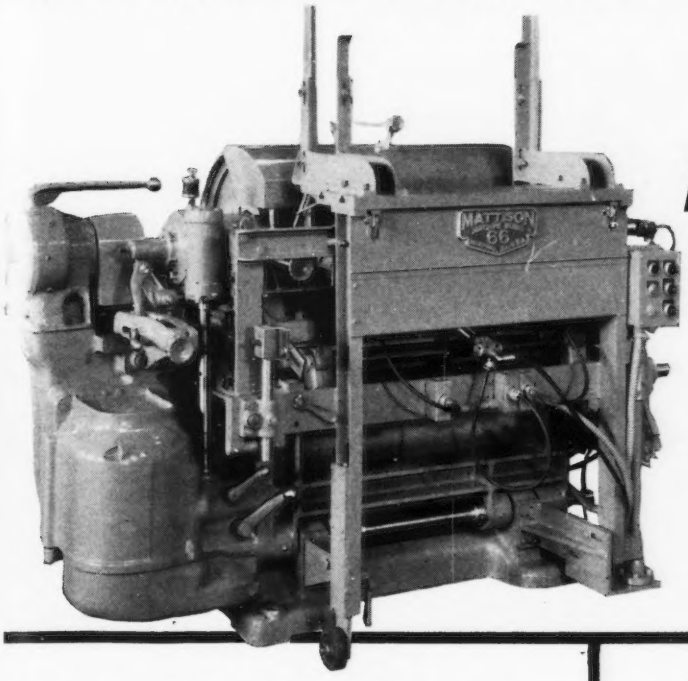
Yugoslavians Visit National Executive Office

While visiting forest products research and industrial organizations in the United States under the auspices of the ICA, Dr. Ivo M. Horvat, University of Zagreb, Yugoslavia; and Ilija Devic, Novi Sad, Yugoslavia, visited the National Executive Office early in February.

Both gentlemen expressed deep interest in FPRS and the Journal. The University of Zagreb is one of many overseas research institutions that receives the Forest Products Journal.

While in the United States, Dr. Horvat will work closely with Eric Anderson, Dept. of Wood Products Engineering, College of Forestry, Syracuse, N. Y. Mr. Devic will work with Sig Johnson, North Carolina State College, Raleigh, N. C.

NEW MATTISON "66" SHAPING LATHE OPERATES AUTOMATICALLY



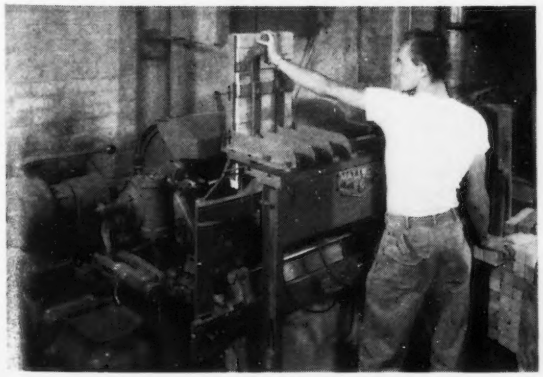
Field tests prove that precision wood-turning operations are done faster . . . with minimum supervision.

Low-cost turning is made possible by automatic cycling of this new Mattison lathe—from centering the piece and engaging knives to ejecting the finished turnings.

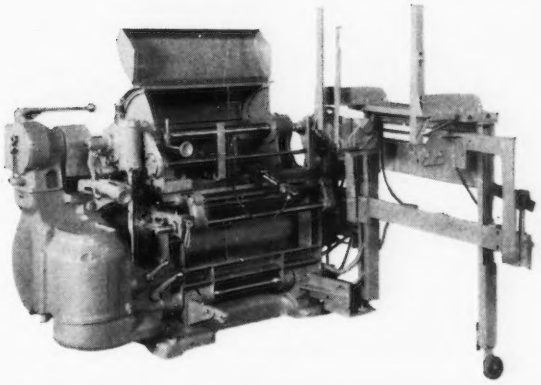
Air power operates the automatic motions of tailstock, carriage, and steadyrest. Easily adjustable to any required production rate. Mattison "66" handles stock from $\frac{3}{4}$" to 4" square and up to 30" long.

EXAMPLES OF SAVINGS: Here are some of the records established by the Mattison "66" at Bergmann Wood Turning, Chicago: Average production of 2400 turnings in 8 hours tripled former results; rough maple stock turned at the rate of 7 pieces per minute instead of 2 pieces—average on manually operated lathes.

Operator just makes the setup and pushes the button; one man can easily keep two automatic lathes in operation simultaneously.



HOPPER-FEED ATTACHMENT is new convenience feature



Once the hopper is loaded, feeding is automatic. Can be swung away from lathe, giving easy access to knives for whetting, touching up, or setting. Write for details today.

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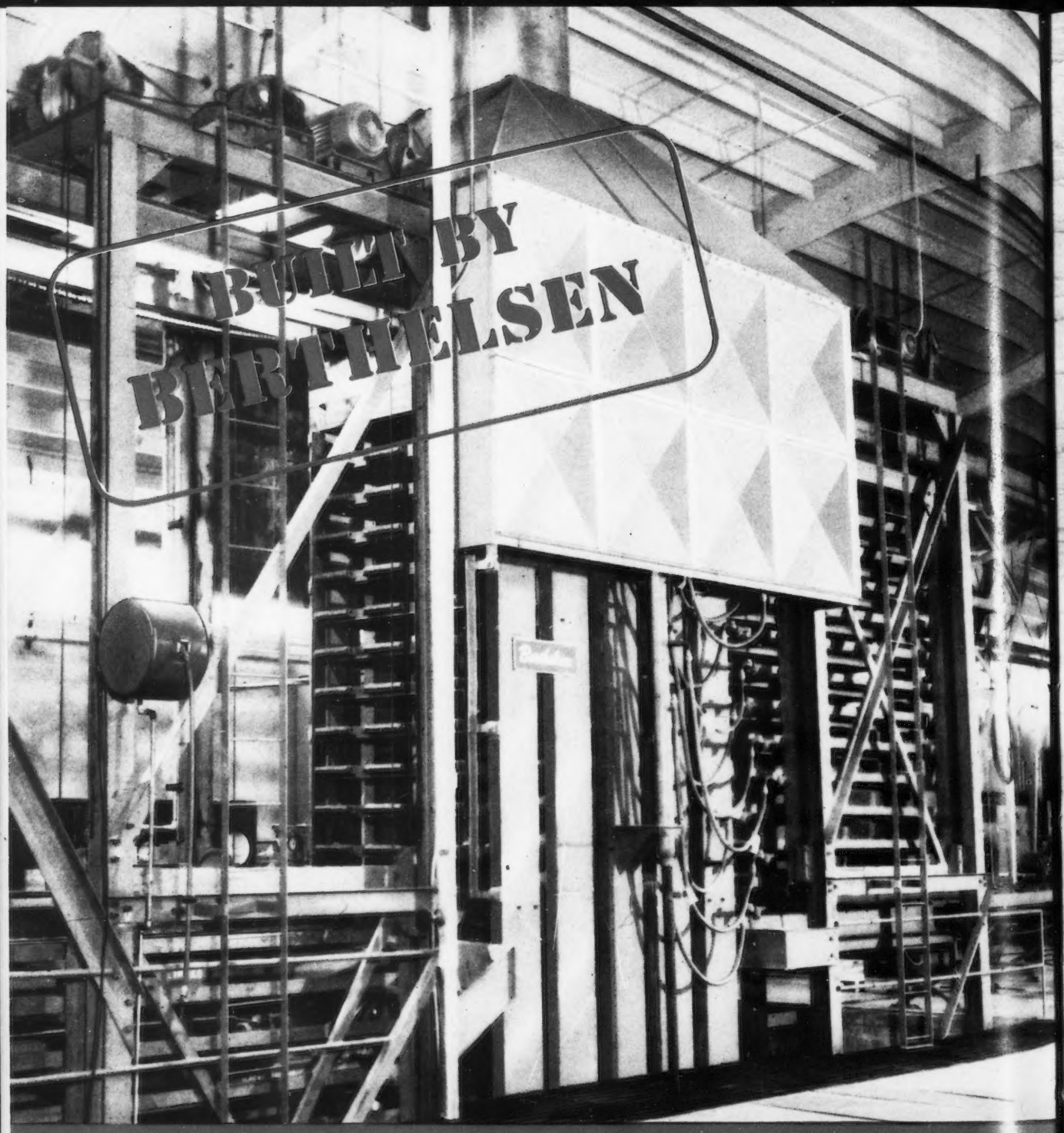

This Multi-opening Berthelsen Press for reconstituted particle, flake or fiber board production was engineered and built for the **Brownsville Particle Board & Associated Products Inc.** in Brownsville, Oregon.

The **first** press designed specifically for reconstituted board production, it incorporates many features that are engineering "firsts" for this type of equipment:

- Chambered high thermal capacity main and intermediate platens with defined minimum deflection tolerances
- Multiple frames, resistant to longitudinal axial thrust loads as well as normal compression pressures
- Longitudinal thrust bearings on each platen in addition to standard platen guides
- "Electric Brain" pressure system, wherein the rate of platen closure is automatically controlled by rate of cure.

You too, can benefit from Berthelsen "engineering know-how" by specifying that the automatic hydraulic hot press equipment you need in your plant be **"Built by Berthelsen."**

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